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Infestation Density and Distribution of Several Important Pests in Western Germany*

by Dr. habil. Hermann Peters, Lecturer

During the first ten years following the war, we continually found that the measures taken to control pests were often inadequate particularly from the aspect of health protection, a condition which was highly regrettable and which gave rise to most justified concern.

This was partly due to the fact that our level of knowledge had fallen well below that of such countries as America as the result of our isolation during the war. On the other hand, we were also severely handicapped because we did not have the benefits of an exchange of know-how with countries which had more experience in this field. This would at least have precluded repetition of errors and have prevented the losses which were suffered unnecessarily. In addition to this, the simplest way of making our measures more effective, namely by means of centralized organization and supervision, did not appear practicable at the time.

The many shortcomings which to all intents and purposes arose out of this lack of cooperation, were made all the more apparent when the situation was compared with the exemplary organization of a neighbouring branch, the plant protection service. In fact the obvious economic losses in the fields and in the forest seemed to create a deeper impression on the authorities than the impairments to the hygiene of the population, in which unfortunately — and here one remembers the fly plague — the interrelationships between cause and effect are never so evident as in the case of attacks by field mice or bark beetle infestation.

During the last six years, however, there has been no lack of effort on the part of the zoological section of the public hygiene service to arouse and deepen the interest and understanding of our town authorities, in particular, concerning the control of pests but we must honestly admit that the greatest, or at any rate the most persistent encouragement and incentive came from the Americans.

For more than four years, vermin control has been carried out regularly and most thoroughly in each town occupied by Americans. The work has been done by well-trained and strictly supervised personnel equipped with the most modern of preparations and equipment. Moreover, it was noticeable that no attempts were made simply to copy the methods conventional in the United

* Enlarged version of a paper read before the German Society for Hygiene and Microbiology, Kissingen, April 30, 1955.

States — on the contrary, the entire organization was carefully built up to conform with German conditions.

These measures alone ought to have had a generally favourable effect at the time, and should have produced really pleasing and positive results. It must, however, be considered that from the very outset contacts had to be established with the German administrative authorities, in particular the local authorities, and continuous efforts were made by means of consultation and practical assistance to encourage them to give their coordinated cooperation.

During the past few years it has been a very satisfying task for me to establish and maintain these relations because from the close contact set up for the first time with many West German municipalities, it was possible to gain an impression of the present distribution and infestation density of important pests to hygiene, which had never been possible before.

Material

Records for such an extensive survey were now available in the form of results from continuous observations made in 52 towns (from August 1952 to March 1955), plus the evaluation of a supplementary inquiry directed at the beginning of 1955 to 311 town and state Public Health Offices.

Consequently a relatively dense network of control points was set up all over Western Germany (see Fig. 1). This guaranteed that the results would to a certain extent be generally binding provided the sources of information could be regarded as fairly reliable. A close check, however, could be kept on this because in both investigations the material was collected not only through completely separate channels but also by two entirely different methods.

The continuous observations were conducted with a maximum of exactitude and in full detail, and the results were recorded daily, but the

Inquiry

was kept brief and general. It was limited merely to establishing what overall impression the respective public health authorities had gained with respect to the occurrence of certain pest classes in their district. Past experience had shown that the majority of offices could not be expected anyway to carry out systematic or even statistically recorded observations, so that only five stages of infestation density were included in the questionnaires. These were then given a certain rating in order to facilitate the necessary conversion to figures (see Table 1a).

The first complete compilation of this information (Table 1b), however, at first produced a somewhat unsatisfactory result, although this had been feared from the outset. Only about two-thirds of the offices to which questionnaires had been sent, gave answers which were in any way utilizable, and even after reminders had been circulated very few of the outstanding questionnaires were returned.

On the other hand, public health officers (M. D.) participating in the inquiry showed keen interest which was actually contrary to expectation. Refusals on principle to submit replies were exceptional. Often the information submitted was actually more detailed than requested, and I am pleased to say that offices which left their public hygiene workers or local pest control operators to fill in the questionnaires were in the minority.



Fig. 1:

Distribution of the 227 control points throughout Western Germany

- = Inquiry only
- + = Continuous observation only
- ★ = Inquiry and continuous observation

It is, therefore, only a question of proper organization — and also a matter of including these points in lectures to students entering the profession — in order to boost up the exchange of know-how and cooperation between our public health offices also in the field of pest control. In view of the result obtained from this inquiry, it can hardly be denied that in this respect more should be done than in the past. At all events the present state arising out of the unconcernedness shown on the one hand and the lack of knowledge on the other hand, is not in keeping with the high standard which always characterized Germany's Public Health Service in the past and, moreover, it is most distressing compared with the resourcefulness of other countries.

Concerning the second part of my studies, the

Continuous Observations,

it should always be borne in mind, insofar as they refer to buildings, that these naturally included different utilization types so that they accordingly had a most varying ecological character and, therefore, must also have had a very dissimilar power of attraction for animals.

The extent to which the occurrence of the different pest classes, as concluded from the infestation of the total number of these buildings, can really

Table 1a: Rating groups of the questionnaire

Density of infestation	Hardly detectable	Weak	Moderate	Serious	Extremely serious
Rating	1	2	4	6	10

Table 1b: Result of the inquiry

	abs.	%		
Inquiries	311 =	100		
Not answered	81 =	26.0		
Reminders	55			
Answered following reminder	9 =	2.9		
Total No. of answers	230	74.0 =	100	
Answer refused on principle	3	=	1.3	
No records	30	=	13.0	
Utilizable answers	197 =	63.34 =	85.0 =	100
according to information of other authorities	8		=	4.1
according to information of private pest control operators	6		=	3.0
according to own experience	183		=	92.9

be regarded as representative of the conditions in the housing estates of Western Germany depends firstly upon the classification of our buildings in types expressed as percentages, whereby the sub-division can be based upon the number of buildings or upon their effective floor space. At all events allowance must be made for these values when evaluating the findings. Moreover, there is another restriction to be taken into account in that on the one hand our observations were carried out almost exclusively in town buildings while on the other hand the inquiry reports the average state in all sizes of housing estates; furthermore a number of useful types, for example large supply plants such as slaughterhouses, are missing, and finally the actual slums were not included. However, even if the slums were to have been included they would not have any really great bearing on the final assessment of the density and rate of pest infestation in flats because slums, I am happy to say, constitute only a small fraction of dwelling houses in our towns. Just the same a comparison with figures obtained in old parts of towns would be most interesting.

According to Table 2, there were hardly any differences between the two observation years with respect to the type classification of the buildings, although there were definite differences between the two reference values, number and area. Here, the proportion "temporary accommodations (hotels etc.) to apartments" is chiefly affected. This is quite understandable because with these two types the building units differ most considerably with respect to the effective floor space.

Table 2: Buildings under continuous observation.

Useful types expressed in percentage, based on the number and living space.

	No.		Space	
	1953 %	1954 %	1953 %	1954 %
Temporary accommodation (Hotels etc.)	7.98	7.46	20.23	20.82
Apartments	49.09	51.96	29.57	33.47
Dining rooms and kitchens	3.60	3.35	3.60	3.70
Store-rooms (warehouses)	10.69	9.78	14.28	11.98
Administration buildings	2.98	2.93	6.34	6.12
Workshops	4.22	4.26	7.18	7.33
Hospitals	0.54	0.52	1.78	1.95
Miscellaneous types	20.86	19.71	16.96	14.59
Totals	100.00	100.00	100.00	100.00

During the observations, however, records were noted not only of the re-infestation of a building but also of the number of treatments required to eradicate the pests as a possible standard for the intensity of the infestation.

In order to obtain comparable relative figures, the infestation values can be placed in relation to the mass of buildings under observation, with either

the number of buildings or their effective floor space* as the reference value. The first figure will then express the frequency of the infestation of a type of building by certain pests, and the second the actual density of their occurrence.

It should, however, not be forgotten that both values are only indices, and that especially the infestation based on the number of buildings cannot be compared to the "infestation of buildings expressed in percent". On the one hand our records show in each case the total of infested sites observed during one year or one month while on the other hand no distinction was made as to whether and how often these infested sites happened to be in one and the same building. "Infestation of buildings expressed in percent" is understood to mean the percentage of buildings infested in one housing estate at the same time.

Direct information, however, is attainable from the material on hand with respect to the quantitative proportion of the pest classes to each other, either as their percentage of the sum total of reported infestations or treatments (see Table 6a, c), or by comparing the infestation density (cf. Table 6b).

This means that a number of very informative figures are available, which can be supplemented by a corresponding evaluation of the frequency of the treatments carried out. Presuming that the working methods are all the same, differences in the rapidity at which an infestation can be eliminated again, may serve as an indication of the infestation rate (this, however, need not by any means be identical with the distribution density of a pest). Naturally there is also the possibility that either the powers of resistance of the various pest classes differ or their actual source of origin is located outdoors and consequently out of the range of the direct effects of our control measures. Corresponding deviations are at any rate best indicated by the proportion "infestation : treatment", in other words an index which reveals how often a new infestation has to be dealt with on the average (cf. Table 6d).

At this stage a short explanation should be given on the selected zoological sub-division of the term "pest", which could not be extended beyond the systematic knowledge of my co-workers and all included in the inquiry. We have, therefore, understood rodents to mean rats on the one hand and mice on the other, whereby it was mostly impossible to differentiate between common rats and brown rats. Mice inside buildings are understood to be common mice, and common wood mice which often make their way into buildings in Autumn. The rodents referred to in the field will in the main be field mice. The insects, on the other hand, include species which can hardly be mistaken such as crickets, bed bugs and crab lice, genera such as Vespidae, families such as ants and silverfishes, or even complete orders such as cockroaches and fleas. But these are always groups where there is no doubt as to what species they must include, unfortunately with one exception, namely the very complex collective name of pantry pests. The larder beetle has been chosen as their representative for the purpose of the illustrations in this paper without there being any deliberate intention of attributing particular importance to it.

* Effective floor space = sum of the floor space of all rooms inside a building (for dwelling houses the "living space"); cf. Peters, H.: „Biologie einer Großstadt“, p. 44, Verlag Hörning, Heidelberg.

Results

General survey

In order to gain a general impression of the distribution and infestation density of the most important pests in Western Germany, it is advisable to start with the work done insofar as it was necessitated by the actual occurrence of vermin.

The respective amounts of working time required for the direct control of rodents and insects respectively (Table 3) can be derived from the means recorded during the last two and half years. This time can then be compared with the percentage share of treatments for the control of rodents and the control of insects.

Table 3: Ratio of rodent control to insect control according to work done.

	Percentage share of working time	Percentage share of treatments 1953	1954
Rodents			
in buildings	16	28.4	30.4
outdoors	5	—	—
Insects			
in buildings	74	71.6	69.6
outdoors	5	—	—

In our investigations brought about chiefly by the demands of health protection, the ratio of control measures in buildings to those outdoors was on the whole the reverse of that for plant protection, which is only natural. Nevertheless, the eradication of rats on refuse dumps and field mice on grass areas, e. P. sports fields, is also of hygienic importance.

The conditions for the occurrence of rodents and insects differ too greatly, however, for the distribution of both groups in the different types of buildings not to be discussed separately.

The corresponding records are given in Tables 4a and b, whereas Table 5a gives the results for insect infestation.

In comparison with dwelling houses, the infestation by insects in buildings where kitchens and large dining rooms are located is, therefore, expected to be $2\frac{1}{2}$ to 3 times greater, in hospitals twice as great, and in temporary accommodation $1\frac{1}{2}$ times as great. The dwelling houses themselves, just like administration buildings and workshops, are somewhat above the total average, whereas store-rooms are considerably below. The expected frequency of infestation for store-rooms is only $\frac{1}{5}$ to $\frac{1}{6}$ in comparison with kitchens and approximately 50 % in comparison with dwelling houses.

With respect to the density in which an infestation makes itself manifest — in other words based on the effective floor space — the different types of buildings become classified in a somewhat different order. In this case it is only

the kitchens and apartments which are above the total average. The former are 1½ times higher than the latter, and both are 1½ to even 8 times higher than the remaining groups.

Buildings comprising kitchens, hospitals and temporary accomodation are, therefore, the useful types most exposed to the danger of infestation but in

Table 4: Useful types of buildings according to "exposure to danger" and infestation density*

a) Insect infestation based on:

Type of building	No. of buildings		Area of buildings**	
	1953	1954	1953	1954
		%		%
Temporary accomodation (hotels etc.)	95.50	179.04	89.62	188.83
Apartments	56.17	105.30	47.16	99.36
Dining rooms and kitchens	140.06	262.57	130.83	275.66
Store-rooms (warehouses)	23.01	43.13	25.07	52.82
Administration buildings	56.69	106.28	66.19	139.46
Workshops	53.92	101.08	49.30	103.87
Hospitals	109.54	205.36	97.01	204.40
Miscellaneous types	29.06	54.48	24.76	52.17
Mean	53.34 = 100		47.46 = 100	

b) Rodents, based on:

Type of building	No. of buildings		Area of buildings**	
	1953	1954	1953	1954
		%		%
Temporary accomodation (hotels etc.)	36.26	206.72	32.87	198.49
Apartments	7.50	42.75	6.84	41.60
Dining rooms and kitchens	55.69	313.56	50.23	303.32
Store-rooms (warehouses)	32.25	182.40	36.45	220.10
Administration buildings	23.48	133.86	24.62	148.67
Workshops	34.00	193.84	33.75	203.80
Hospitals	30.30	172.74	36.81	222.28
Miscellaneous types	15.36	87.57	14.94	90.21
Mean	17.54 = 100		16.56 = 100	

* The frequency of infestation (based on the number of buildings) is an expression of the power of attraction a certain useful type of building has for pests, and is at the same time a standard for the exposure of the buildings to the danger of infestation; on the other hand when based on the total utilizable floor space, an index of the infestation density is obtained.

** 1 infestation to 100,000 square metres.

Table 5:

Order of the useful types of buildings

according to "exposure to danger of infestation" and infestation density, expressed in percentages of the respective annual mean

a) Insects

Infestation, based on the number of buildings

1953

Kitchen establishments	262.57
------------------------	--------

Hospitals	205.36
Temporary accomodation (hotels, boarding houses etc.)	179.04
Administration buildings	106.28
Apartments	105.30
Workshops	101.08

Miscellaneous types	54.48
Store-rooms (warehouses)	43.13

1954

275.66	Kitchen establishments
--------	------------------------

204.40	Hospitals
188.83	Temporary accomodation (hotels, boarding houses etc.)
139.46	Administration buildings
103.87	Workshops
99.36	Apartments

52.82	Store-rooms (warehouses)
52.17	Miscellaneous types

M

Infestation, based on areas of buildings

Kitchen establishments	262.53
------------------------	--------

Apartments	174.74
------------	--------

249.41	Kitchen establishments
--------	------------------------

154.24	Apartments
--------	------------

M

Temporary accomodation (hotels, boarding houses etc.)	70.59
Miscellaneous types	66.95
Hospitals	62.25
Workshops	59.32
Administration buildings	49.97
Store-rooms (warehouses)	32.29

70.46	Miscellaneous types
67.66	Temporary accomodation (hotels, boarding houses etc.)
66.78	Administration buildings
60.41	Workshops
54.53	Hospitals
43.10	Store-rooms (warehouses)

Table 5:

Order of the useful types of buildings

according to "exposure to danger of infestation" and infestation density, expressed in percentages of the respective annual mean

b) Rodents

Infestation, based on the number of buildings

1953

Kitchen establishments	313.56
------------------------	--------

Temporary accommodation (hotels, boarding houses etc.)	206.72
Workshops	193.84
Store-rooms (warehouses)	182.40
Hospitals	172.74
Administration buildings	133.86
Miscellaneous types	87.57

Apartments	42.75
------------	-------

M

1954

303.32	Kitchen establishments
--------	------------------------

222.28	Hospitals
220.10	Store-rooms (warehouses)
203.80	Workshops
198.49	Temporary accommodation (hotels, boarding houses etc.)
148.67	Administration buildings
90.21	Miscellaneous types

41.60	Apartments
-------	------------

Infestation, based on areas of buildings

Kitchen establishments	317.44
------------------------	--------

Store-rooms (warehouses)	137.65
--------------------------	--------

Workshops	113.77
Miscellaneous types	107.59
Temporary accommodation (hotels, boarding houses etc.)	81.49
Apartments	71.00
Administration buildings	62.94
Hospitals	52.32

M

274.53	Kitchen establishments
--------	------------------------

179.31	Store-rooms (warehouses)
--------	--------------------------

121.94	Miscellaneous types
118.61	Workshops
71.20	Administration buildings
71.11	Temporary accommodation (hotels, boarding houses etc.)
64.13	Apartments
59.30	Hospitals

Table 6:

Reciprocal proportion of the most important pest groups in buildings

Insects	Continuous observation				Inquiry									
	Reference value: Total infestation				e 1—4 Percentage share in total rating									
	Reference value: Effective floor space				f Average rating									
Reference value: Total treatments				SE, SE + SW, N = Districts of observation (cf. Table 1)										
G = Western Germany, total														
Insects	1953				1954				SE, SE + SW, N				G	
	a	b	c	d	a	b	c	d	e 1	e 2	e 3	e 4	f	
Gnats	17.4	12.4	17.1	1:1.8	14.6	9.5	15.1	1:1.8	11.7	11.8	11.2	11.6	3.0	
Flies	28.8	20.6	38.3	:2.5	32.5	21.2	38.3	:2.0	14.3	14.4	12.9	13.9	3.5	
Wasps, hornets	3.8	2.7	3.2	:1.6	3.0	1.9	2.4	:1.3	10.4	10.4	7.2	9.3	2.4	
Ants	13.6	9.7	10.9	:1.5	12.3	8.0	11.0	:1.5	10.3	10.4	10.6	10.4	2.7	
Crickets	2.7	1.9	2.0	:1.4	1.9	1.2	1.4	:1.3	5.0	4.9	5.0	4.9	1.3	
Cockroaches	10.3	7.4	10.2	:1.8	11.4	7.5	11.2	:1.6	8.5	8.9	8.5	8.8	2.2	
Silverfishes	1.8	1.3	1.6	:1.6	1.6	1.0	1.3	:1.4	7.1	6.8	7.9	7.2	1.9	
Pantry pests	1.8	1.3	1.7	:1.7	2.1	1.4	1.7	:1.4	5.3	5.5	4.6	5.1	1.3	
Moths	13.5	9.6	9.7	:1.3	16.0	10.4	13.9	:1.5	8.9	8.9	10.9	9.6	2.5	
Bugs	1.9	1.4	1.4	:1.3	1.2	0.8	1.1	:1.6	7.1	6.6	7.6	7.0	1.8	
Fleas	1.4	1.0	1.0	:1.4	0.9	0.6	0.6	:1.2	3.9	3.9	5.5	4.4	1.1	
Head and body lice	0.8	0.5	0.6	:1.4	0.1	0.1	0.1	:1.2	4.5	4.6	4.4	4.5	1.2	
Crab lice	2.1	1.5	2.1	:1.9	2.4	1.5	2.0	:1.4	2.7	2.6	3.5	2.9	0.8	
Rodents														
Common mice	—	—	—	—	—	—	—	—	28.3	27.7	23.9	26.4	2.7	
Field mice	—	—	—	—	—	—	—	—	31.4	31.0	29.8	30.6	3.1	
Mice	70.9	16.6	71.2	:2.1	69.6	15.8	71.8	:2.2	—	—	—	56.9	—	
Common rats	—	—	—	—	—	—	—	—	14.1	15.0	15.7	15.3	1.5	
Brown rats	—	—	—	—	—	—	—	—	26.1	26.1	30.1	27.7	2.8	
Rats	29.0	6.8	28.7	:1.9	30.4	6.9	28.2	:2.2	—	—	7.2	43.0	—	

proportion to the absolute size or effective area of the buildings, the densest infestations of insects are in kitchens or restaurants and in apartments.

The most likely explanation for these conditions is that temporary accommodation, administration buildings and hospitals are probably cleaned more regularly, and in particular these types of buildings by no means offer so many hiding places as an average dwelling house, that is presuming the effective floor space to be the same.

Large dining establishments with kitchens, on the other hand, always have such a great power of attraction for vermin due to surplus foodstuffs lying around that it is simply impossible to prevent repeated occurrences of injurious insects in these buildings.

The overall situation appears somewhat different with respect to rodents (cf. Table 4b and Table 5b).

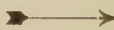
The type of building least exposed to the danger of infestation by rodents is the dwelling house (apartments) whereas in kitchens and large dining establishments the likelihood of finding mice or rats is about six times as great. In comparison with apartment houses, the chances of rodent infestation in administration buildings are twice as great while in the other types of buildings they are $1\frac{1}{2}$ to 4 times as great.

With respect to the infestation density, kitchen establishments again head the list followed by store-rooms and, strange to relate, workshops. Hospitals, apartments, administration buildings, hotels and other forms of temporary accommodation are all below the total average. The reasons for this order of classification are certainly the same as those for harmful insects with the exception that in store-rooms rodents are on the average very active and, therefore, are more capable of gaining access to the products than insects. In addition the occurrence of rodents in non-heated rooms is not interrupted by winter dormancy. On the other hand, the absolutely small quantity of fodder available in apartments may set natural limits to rodent infestation there, whereas the infiltration of insects is assisted by their much greater ability to spread.

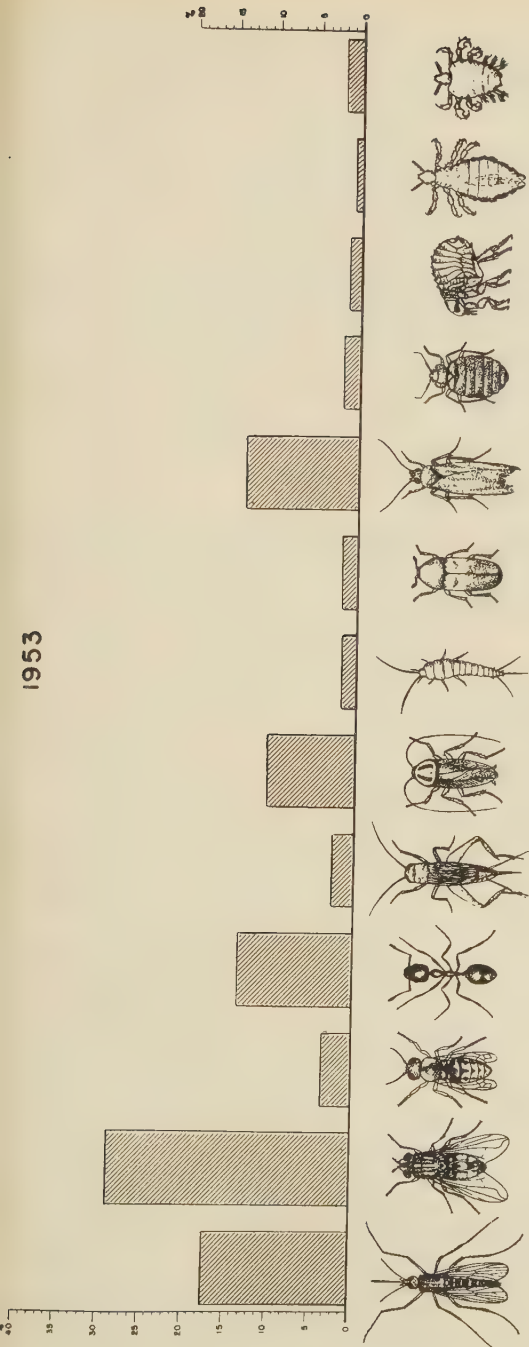
When the material is analyzed further, it will of course be perceived that the participation of the different pests in the infestation of buildings varies greatly, particularly in the case of mice and rats (cf. Fig. 3 and Table 9).

We are, however, more interested to begin with in the reciprocal quantitative proportion of the different pest classes in general, regardless of the types of buildings. Information on this is given in Table 6 where the results of the continuous observations are compared with those obtained from the inquiry. It will be seen from this that there are no basic differences either between the results of 1953 and those of 1954 or between the different subsections of Western Germany, "N", "SW" and "SE". Moreover, the results of the inquiry agree most satisfactorily with those of the statistically significant continuous observations.

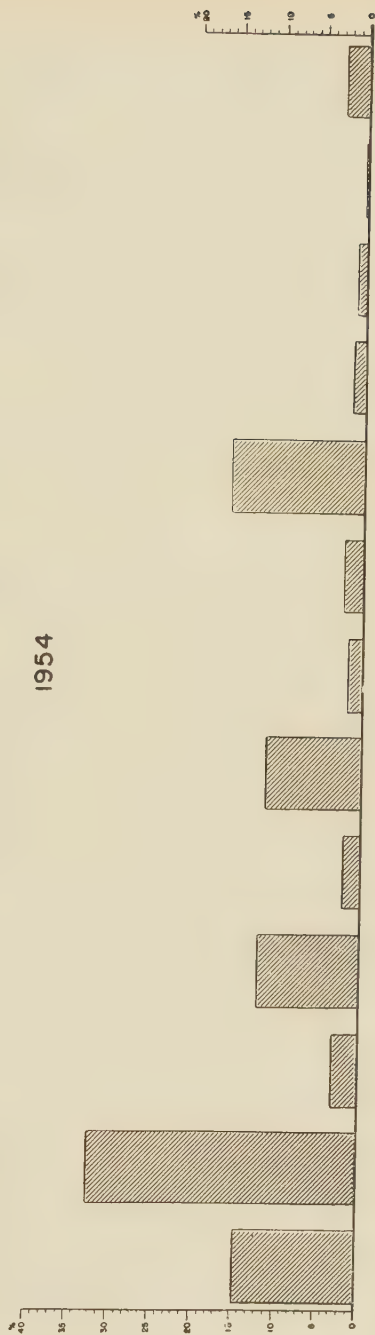
Fig. 2: The frequency of infestation of important harmful pests 1953 and 1954. (Percentage share in total infestation, see Table 6a). The pest types are arranged here — just as in Fig. 3 or Tables 6 and 11 — in accordance with their approximate spatial binding to the house and to human beings, in other words starting in order of housing estate vermin (gnats, flies, wasps, hornets, ants, crickets), apartment vermin (cockroaches, silverfishes, pantry pests with the larder beetle as their representative, moths and bugs) and on to the marked body parasites (lice and fleas).



1953



1954



The results of the inquiry, of course, only permitted a classification of the pests in their order of occurrence but did not allow a recording of the correct quantitative margins between the various classes. For this, the very simple six-value rating was not sufficient.

In order to gain a correct impression of the present situation in Western Germany, it is, therefore, advisable to begin with the results of the continuous observations, such as they are shown in Fig. 2 and in Table 7 (according to Table 6b).

These infestation figures, based on the effective floor space of the buildings, allow direct comparisons to be drawn between both years and between the occurrences of rodents and insects. The list is headed by the flies which are prevalent everywhere, and they are followed by a central group, namely gnats, mice, moths, ants, cockroaches and rats. The order

Table 7: Important pests in the order of their infestation density
(Reference value: Effective area of buildings)

1953		1954	
Flies	20.57	21.22	Flies
Mice	16.63	15.96	Mice
Gnats	12.44	10.44	Moths
Ants	9.73	9.54	Gnats
Moths	9.59	8.06	Ants
Cockroaches	7.38	7.47	Cockroaches
Rats	6.82	6.92	Rats
Wasps, hornets	2.68	1.95	Wasps, hornets
Crickets	1.90	1.54	Crab lice
Crab lice	1.49	1.39	Pantry pests
Bugs	1.37	1.21	Crickets
Pantry pests	1.28	1.03	Silverfishes
Silverfishes	1.27	0.76	Bugs
Fleas	1.02	0.59	Fleas
Lice	0.54	0.05	Lice

of this group, however, varies somewhat during the two observation years. The "mouse density" is rather surprisingly high up the list. Apparently one does not fully realise how widespread is this pest which frequents our homes at night.

The other types, in particular the body vermin, are hardly of any importance, and it is most reassuring to note how much bug and louse infestations have receded in Western Germany since the first years of the war.

On the other hand, the relatively slight occurrence of wasps and hornets is most interesting particularly in comparison with the results of the inquiry, which indicate that Vespidae are found to be much more troublesome than the numerical frequency of their occurrence would suggest.

The differences between the results of the inquiry and those of the continuous observations are due mainly to the fact that the latter report figures in respect of the objective infestation frequency and density whereas the standard of the inquiry is after all a more or less subjective impression, namely to what extent the different pests had proved to be a disturbing factor at one place.

It is extremely difficult to make binding statements on the intensity of vermin infestation. At the most one could attempt to compare the different classes with respect to the number of treatments required to eradicate them but it is doubtful whether use can really be made of the corresponding values recorded in the material available.

Even if a close check were to prove that the differences determinable from this material (cf. Table 6d) are statistically significant, the most obvious explanation would be that pests which breed away from the buildings are much more difficult to get rid of than vermin actually specific to houses. In our case this theory is definitely applicable to flies, gnats and rats, and possibly also to mice. On the other hand, the treatment index for cockroaches is probably so high because a radical eradication of this pest is more difficult than with other harmful insects. In other words this would mean that much greater resistance is offered, not to the applied preparation but only to the methods.

But even with these points settled, we still do not have a definite basis for deciding which infestation densities are actually to be rated as "serious", and how we can grade the discussed classes of pests according to the above rating. The inquiry is the only source which gives several useful indications as to how this can be done. Moreover, we would be well advised not to choose the somewhat colourless average value as the standard. In fact it does not rise above "average" for any class, which means that it furnishes at the same time the comforting proof that at no place in Western Germany today do pests of hygienic importance occur in the form of a plague. On the other hand the percentage of answers which show the occurrence of a certain pest to be "serious" or even "very serious" might be taken as the safest basis for drawing conclusions, provided a widespread distribution of average density is to be assumed simultaneously (Table 8a).

When the order thus obtained is compared with the sequence drawn up according to the infestation density (Table 6b), the following picture is produced (cf. Table 8b):

Table 8a: Infestation rate according to the results of the inquiry.
Percentage distribution of the answers in four value ratings, and total mean.

	"Serious" to "very serious"	"Average"	"Weak"	"Hardly detectable" to "zero"	M (cf. Tables 1a and 6f)
Insects					
Flies	18.77	46.20	23.35	10.65	3.58
Gnats	14.20	35.52	22.84	27.40	3.00
Ants	12.17	28.42	29.44	29.94	2.70
Clothes moths	7.09	28.92	33.50	30.45	2.48
Wasps, hornets	11.16	20.81	29.94	38.06	2.41
Cockroaches	6.59	22.32	34.51	36.54	2.27
Silverfishes	3.03	16.23	34.01	46.67	1.86
Bugs	3.54	11.15	33.50	51.77	1.81
Pantry pests	3.54	7.60	21.31	67.50	1.34
Crickets	0.50	7.60	20.81	71.06	1.28
Fleas	0.00	2.02	24.36	73.60	1.14
Lice	0.00	2.03	22.33	75.62	1.16
Crab lice	0.00	0.00	3.04	96.95	0.75
Rodents					
Brown rats	8.11	38.05	31.97	21.81	2.84
Common rats	5.57	9.12	21.82	63.44	1.56
Field mice	18.76	31.96	20.30	28.92	3.13
Common mice	6.09	37.01	36.54	20.29	2.70

Flies continue to maintain their absolute domination among pests of hygienic importance both from the subjective and the objective aspect. Even in the second group of greatest infestation there are hardly any deviations with respect to mice, gnats, moths and ants. However, the assumption we already expressed concerning the common mouse (Table 7) is confirmed, namely that this small, sly rodent is given less attention than its actual infestation density deserves, whereas the brown rat proved to be a far more disturbing factor than expected. Of course, opinions influenced by personal feelings also have much to do with the differences in the rating. For reasons which here cannot be explained in more detail, the rat in contrast to the common mouse is generally regarded as the most "loathsome and repulsive pest". It is a known fact based on old experience that reports on rat infestation received from the general public are mostly exaggerated and vary from "hundreds" to "thousands".

It has already been mentioned that a similar mistake is made when assessing the density of wasp and hornet infestation. This is just as understandable as the over-estimation of the bug infestation whereby the aversion factor again has to be given full consideration. On the other hand, it is really difficult to understand why the harmless silverfishes are considered to be so troublesome — perhaps this is simply a case of confusion with moths, because unbelievable though it may sound *Lepisma* is actually taken here and there in popular zoology for the larva of the clothes moth, and *vice versa* moths seen scurrying rapidly into infested material are often mistaken for silverfishes.

The distribution of the pests in the different types of buildings (cf. Table 11a and Fig. 3), however, is more interesting and of greater practical importance from the ecological aspect than the problem of infestation density. Warehouses, workshops and kitchens are the types chiefly infested by

Table 8b:

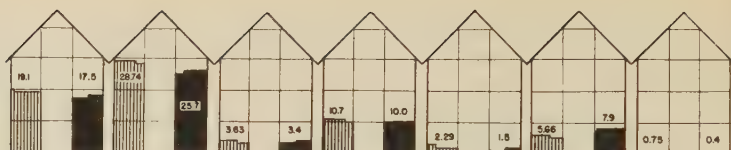
Order of pests

according to estimated infestation rate (inquiry)

and determinable infestation density (observation) (calculated on numbers of flies)

Infestation rate		Infestation density M 1953/54	
Flies	100.00	100.00	Flies
Gnats	76.42	77.74	Mice
Rats	71.04		
Mice	66.33		
Ants	62.47		
Moths	55.42	52.59	Gnats
Wasps, hornets	49.20	47.93	Moths
Cockroaches	44.49	42.56	Ants
		35.53	Cockroaches
		32.87	Rats
Silverfishes	29.64		
Bugs	22.61		
Pantry pests	17.14	11.07	Wasps, hornets
Crickets	12.46	7.44	Crickets
		7.25	Crab lice
		6.38	Pantry pests
		5.50	Silverfishes
		5.09	Bugs
		3.85	Fleas
		1.41	Lice
Lice	3.12		
Fleas	3.10		

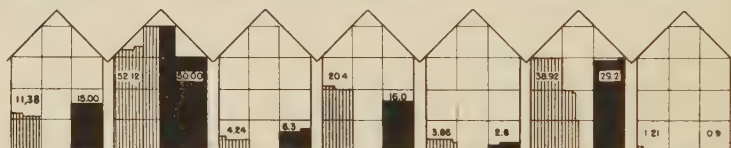
Hotels etc.



Apartments



Dining rooms and kitchens



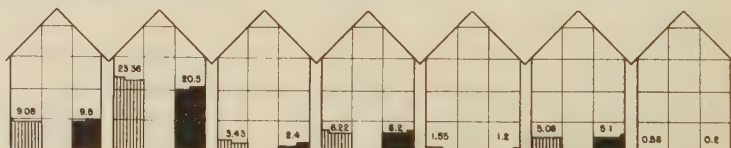
Store-rooms (warehouses)



Administration buildings



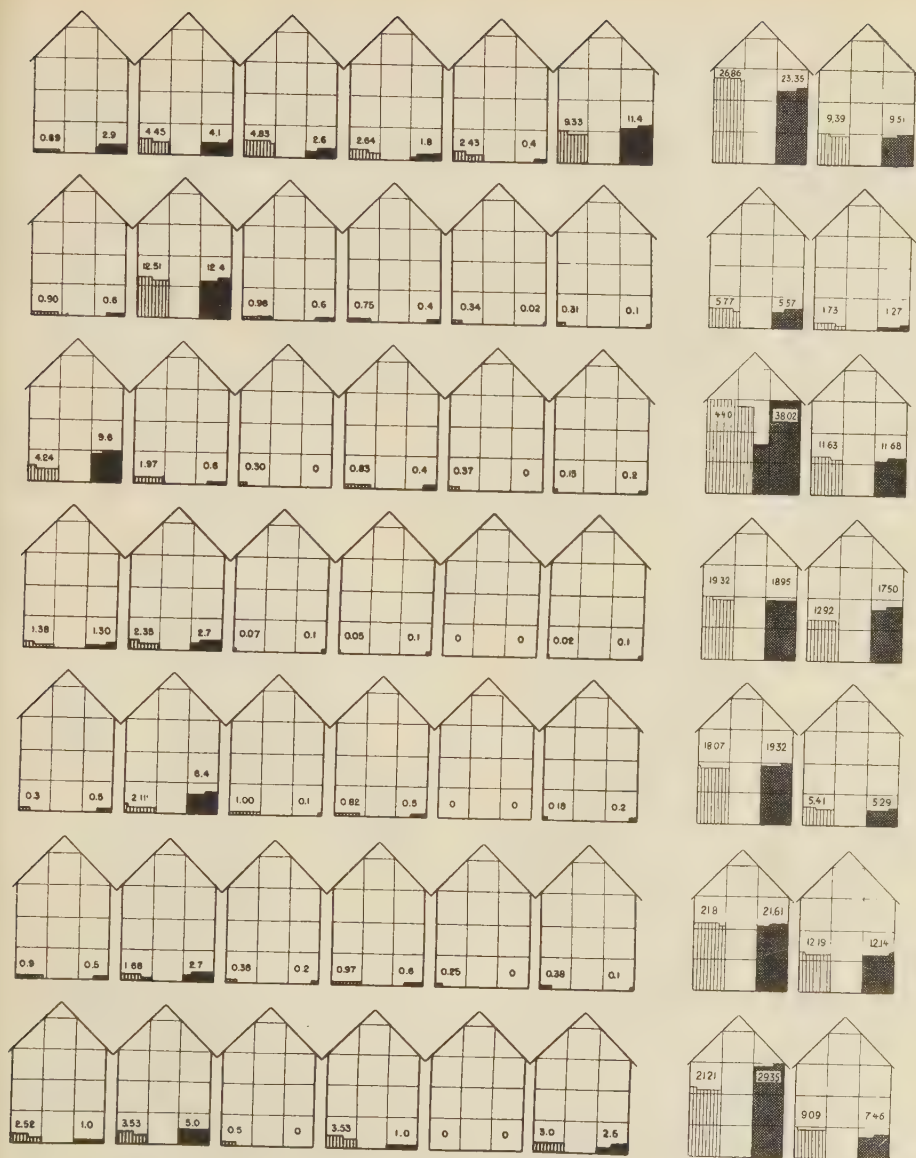
Workshops



Hospitals



Fig. 3: The frequency of infestation in the different types of useful buildings. The reference value is the number of



buildings as the standard for the probability of finding certain pests in one particular type of building (cf. Table 11a)

rats. These are followed by hospitals and accommodation buildings (hotels etc.). At first sight, it appears strange that workshops are so high up the list. But I have previously noticed the preference brown rats show for such places. The excellent hiding places that are offered, for example in a carpenter's shop, most probably constitute the main attraction and outweigh the somewhat unfavourable chances of finding food there.

Administration buildings incidentally are very seldom attacked, and the probability of finding rats in a dwelling house is very slight (1/10) as compared with buildings at the head of the list.

Whereas the overall frequency ratio of rats to mice is 1:2 in the buildings I investigated, the differences in individual cases are often much greater.

Kitchens and dining rooms (restaurants etc.) are the buildings preferred most by mice. These are followed by hotels etc. and hospitals, and then come — with slight deviation — workshops, administration buildings and store-rooms. Flats, however, are again at the bottom of the list.

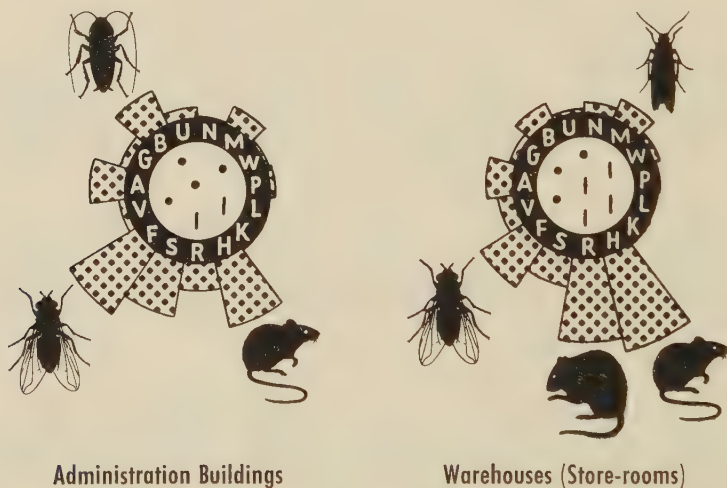


Fig. 4: Infestation density in different useful types of buildings (according to the means of the two observation years 1953 and 1954, cf. Table 11b).

The reference value is the floor space as the standard for the extent to which individual building types are exposed to danger. In addition to this infestation "potency" in general, it will be recognized that vermin annoyance is made up in each case of completely different main components. It may consist solely of insects or, on the other hand, have a greater "flavour" of rodents (inner circle). But soon afterwards a reappearance is made by mice, then moths or perhaps it will be the kitchen vermin such as cockroaches, crickets and ants which predominate in the overall picture (sectors).

Inner circle: Rodents = *, insects = I, for each 10 infestation reports per year and 100,000 square metres.

Black circle:

S = Gnats
F = Flies
V = Wasps, hornets
A = Ants
G = Crickets
B = Cockroaches
U = Silverfishes
N = Pantry pests (insects)

M = Moths
W = Bugs
P = Fleas
L = Body and head lice
K = Crab lice
H = Common mice
R = Rats



Hotels etc.



Dining rooms
and kitchens



Workshops



Hospitals

Flats

Flies are to be found everywhere as the chief pest within the synanthropic insect world. Ant infestation, too, is distributed rather evenly over all types of buildings. On the other hand, cockroaches for example move up to second place in kitchens and dining rooms and, moreover, they are often to be found not only in hospitals but surprisingly also in administration buildings. It is often forgotten that in offices, sufficient waste food (left-overs from lunch) is left lying around overnight, at least in waste-paper baskets, to feed an entire army of cockroaches.

The cricket is a decided "hospital insect" whereas the moth naturally concentrates its attacks on flats (dwelling houses) and textile stores.

Furthermore, the distribution of the blood-sucking body vermin is most characteristic. Hotels etc. and hospitals are naturally attacked most because in these types there is far more likelihood of vermin continually being carried in due to the frequent change of residents and patients, respectively.

A very similar picture is obtained when we take the infestation density as the basis, in other words, when we select the effective floor space of the buildings as the reference value (Table 11b). In this way, of course, the infestation "potency" of certain types of buildings such as kitchens and dining establishments will be far more apparent.

In normal dwelling houses, flies and moths, and gnats, mice, cockroaches and ants are the two dominant groups, while in the other biotopes which ecologically are much more one-sided, the order may naturally be quite different. In warehouses, for example, a striking feature is the absolute predominance of mice and rats, or in kitchens the most serious infestations, both relatively and absolutely, are caused by cockroaches and mice (Fig. 4).

It should not be forgotten, however, that such a list has many gaps. Our investigations, for example, did not include such useful types of buildings as bakeries, butcher's premises, market halls and stables which are hives of infestation for rats, mice and cockroaches.

Nevertheless, this survey provided by Fig. 4 clearly shows that in the control of many pests that degree of success has not yet been achieved which is necessary to guarantee a sufficiently high standard of hygiene in dwellings and adequate protection of material, although on the other hand one gains the general impression, particularly from the many supplementary reports received as the result of the inquiry, that vermin infestation has continued to decrease during the last few years in Western Germany.

In addition to these general findings on the distribution of pests of hygienic importance in Western Germany, a number of other noteworthy details were established, particularly with respect to the seasonal and regional differences in the occurrence of the main classes of pests. In dealing with the regional density of distribution, it will be advisable only to compare the values of one and the same type of building. For this purpose, I selected in the continuous observations the flats which numerically are at the top of the list and which have the highest degree of significance statistically, because after all every increase or decrease in pest infestation determined by general local conditions must also be perceptible in dwelling houses.

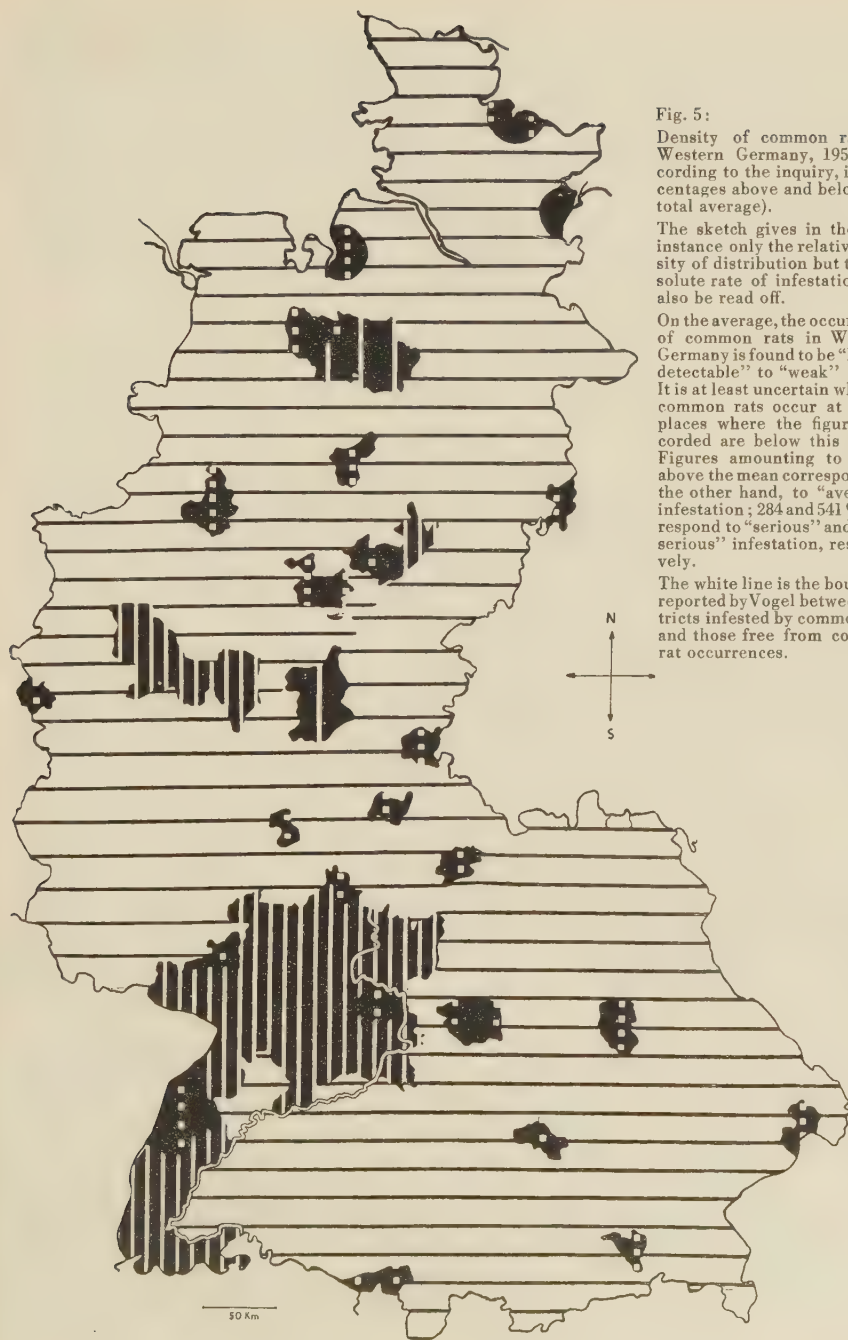


Fig. 5:

Density of common rats in Western Germany, 1954 (according to the inquiry, in percentages above and below the total average).

The sketch gives in the first instance only the relative density of distribution but the absolute rate of infestation can also be read off.

On the average, the occurrence of common rats in Western Germany is found to be "hardly detectable" to "weak" (1-56). It is at least uncertain whether common rats occur at all in places where the figures recorded are below this mean. Figures amounting to 156% above the mean correspond, on the other hand, to "average" infestation; 284 and 541% correspond to "serious" and "very serious" infestation, respectively.

The white line is the boundary reported by Vogel between districts infested by common rats and those free from common rat occurrences.

In the respective sketches (Figs. 5, 6, 10 and 11), the values of the individual observation points are expressed in their percentage deviation from the respective total mean for the purpose of direct comparability (see Table 12). The results of the inquiry were first taken as the basis, and in order to elucidate the interrelationships between large areas an attempt was always made to record as far as possible the predominantly "negative" or "positive" regions (with "4" and "6") as a compact unit. Districts with "serious" and "very serious" infestation ("6" and "10"), however, remain recognizable as "islands" in the calculation of negative regional averages. The continuous observation points are also entered in these sketches, with the exception of Fig. 6. The figures obtained in both years agreed to such a large extent (cf. Table 12) that we were able to confine our remarks to the values of 1954.

Regional and seasonal differences

Rodents

Rats

In the continuous observations, it was decided from the very outset not to differentiate between common rats and brown rats, but in the inquiry an attempt was at least made to gain some information on the reciprocal proportion of the two species even at the risk of mistakes occasionally being made in the identification of the species which meant that these would have to be accepted as sources of error which could not be checked.

According to Table 6f, common rats and brown rats would be assumed to occur in a proportion of 1:2. The fact that this value might also represent a certain expression of the infestation density, can be read from the entry of the individual data on the sketches because the "positive" as well as the "negative" points of common rat occurrence reveal regional relationships which are too evident for them simply to be regarded as results of pure coincidence.

The South-West as an area undoubtedly plagued by common rats is confronted by the eastern region which one recognizes just as clearly to be "negative". "Positive" regions are the Upper Rhine Valley, the south-east and central lowland and parts of the lowland region of the Upper Rhine, Neckar and Taubergäu, the central Franconian basin, the bay of Stuttgart, the Neckar basin and the southern part of the Oden Forest, also a number of small "islands" at Lake Constance, near Passau, Schweinfurt and Parsberg, Aichach and Aibling.

Districts which in parts are completely free from rats or where the infestation is very slight are to be found in the remaining area of Bavaria, the Franconian Alb, the Swabian Alb with fore-land, the southern section of "Upper Gäue" and a large part of the Black Forest.

It seems all the more probable that the present-day distribution of common rats in South-Western Germany has been correctly reported at least in rough outlines when it is considered that the boundaries agree basically with the results Vogel obtained in his inquiry (cf. Fig. 5)*. In this very thorough in-

* Vogel, R.: „Die gegenwärtige Verbreitung der Hausratte (*Rattus rattus* L.) in Südwestdeutschland und die sie bestimmenden Faktoren.“ Jahresh. Ver. Vaterländ. Naturk., Württemberg, 108. Jahrg.

vestigation, it was possible to establish exactly the districts infested by common rats from discovered records with respect to the whole of Baden, Württemberg and also parts of Hesse. In all these districts the general climatic conditions no doubt have considerable influence on the distribution of the common rat. The adjoining negative strip in the north might also be explained by the less favourable weather conditions prevailing in the Hunsrück, Harardt, Taunus and Harz areas. The distribution of districts which at first are weakly and then more seriously infested in Central and North Germany is at first difficult to explain. The lack of common rats in Schleswig-Holstein may also be due to climatic conditions — only the ports report particularly serious infestation in certain cases. On the other hand, it cannot be said with certainty from the material available whether and to what extent consolidated districts of common rat infestation may at some time be established in the remaining area — spreading from Oldenburg, Hannover, Lüneburg, down to Westphalia and into Bergisch Land. One point should not be overlooked, namely that the common rat infestation in the large ports and inland cities are mostly of a completely different origin from those of the smaller municipalities because it is an established fact that with the imports of goods, especially fruit and vegetables, new invasions of rodents are constantly occurring with the result that the pests form colonies in these places. Consequently we have to differentiate in Germany between the infestation of our large towns by new swarms, which originate chiefly from the Mediterranean zone, and the old established strains of common rats. These, however, have definitely been on the move for at least the last thirty years due to the possibilities of their existence being lessened temporarily (up to about the beginning of the present century). During the past few years reports have continually been received of increased occurrences of common rats — I would mention only the district of Miltenberg, Francfort-on-Main, Lörrach and Lübeck — with the result that the boundaries of the infested and non-infested districts, as shown on Vogel's map for 1952, have long shifted farther East. A report of interest in this connection has been received from Wolfach, in which it is alleged that on the ridge of the Black Forest more roof rats are to be found in the houses, but no brown rats. The brown rat occurs more in the valleys. Moreover, woodmen have observed that there are many rats in the woods and forests at the time of the "fir blossom".

The first report was without doubt very correctly explained by Vogel when he said that the old remote farms with their high indoor temperatures provide a very favourable house climate for roof rats. The second report, however, again raises the question whether rats change their surroundings at different times of the year, a fact which has often been maintained.

I could well imagine that "taking a summer holiday" is more a characteristic of the common rat than of the brown rat which, once it has settled in a particular district, gives the impression that it prefers to stay there and not leave the underground structures. At all events, it is possible that *Rattus rattus* is more of a roaming rodent than *Epimys norvegicus*.

The infestation density of the brown rat is also distributed in a most characteristic manner (Fig. 6). The sketch is based on the results of both the inquiry and the continuous observations. This appears to a certain degree to be quite justified because in view of the type of buildings kept under check the species involved must have been chiefly brown rats and, moreover, a large number of the places were in districts where there was a low infestation rate of common rats. In these observations the regional deviations from the average

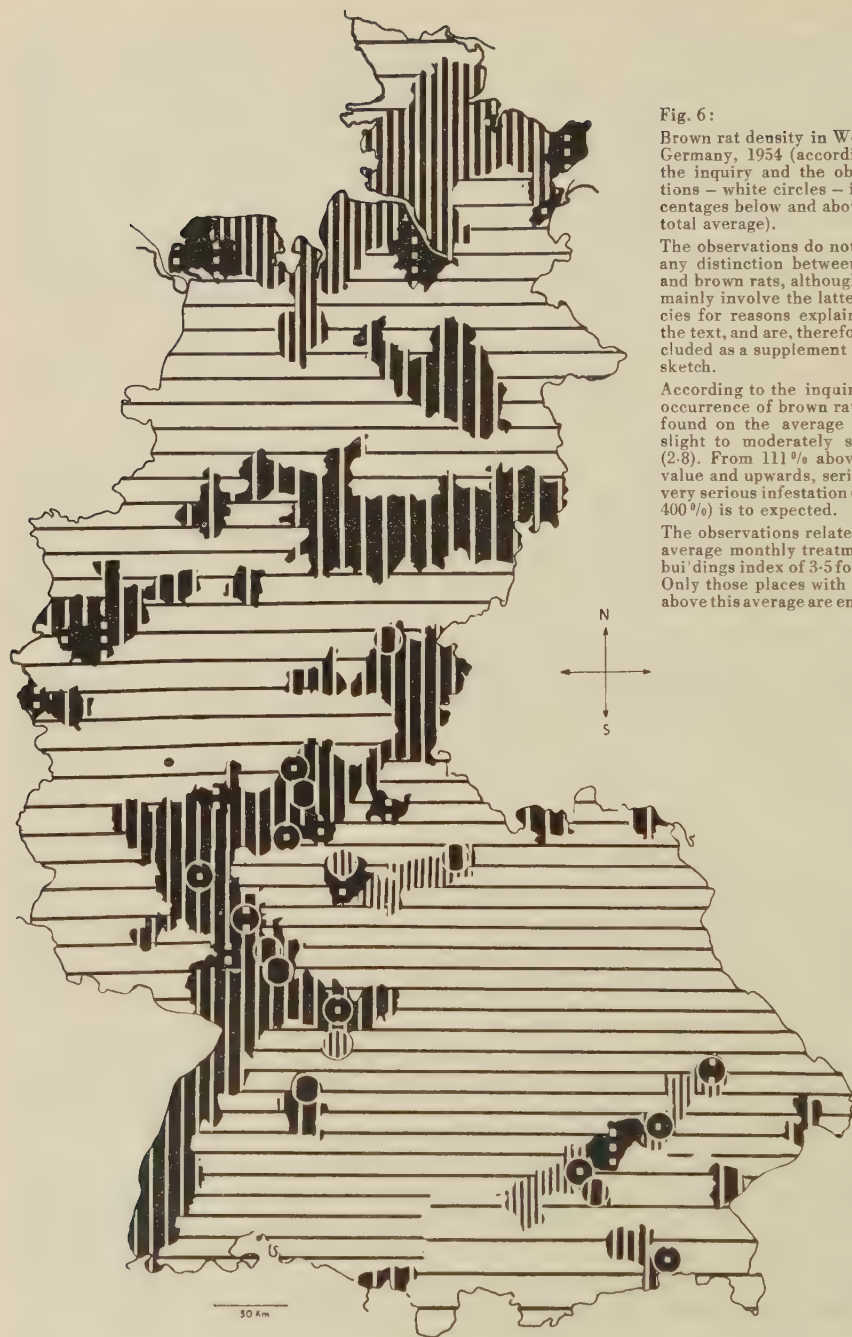


Fig. 6:

Brown rat density in Western Germany, 1954 (according to the inquiry and the observations – white circles – in percentages below and above the total average).

The observations do not draw any distinction between roof and brown rats, although they mainly involve the latter species for reasons explained in the text, and are, therefore, included as a supplement in the sketch.

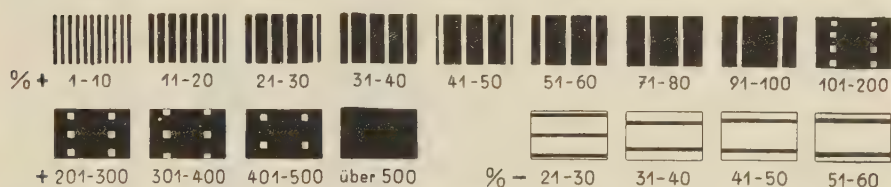
According to the inquiry, the occurrence of brown rats was found on the average to be slight to moderately serious (2.8). From 111% above this value and upwards, serious to very serious infestation (above 400%) is to be expected.

The observations relate to the average monthly treatment of buildings index of 3.5 for 1954. Only those places with values above this average are entered.

infestation density of the two previous years were so constant that it must undoubtedly have been a case not only of temporary but also of fundamental differences between individual regions. Regardless of whether I take the percentage infestation of buildings as the basis, or an index which makes allowance for the consumption of poison, set traps and the number of rats caught, the region of Bavaria and Franconia where there are very few rats always stands out clearly against a sector of serious infestation stretching from Munich to Straubing. The district along the Neckar between Heilbronn and Worms also appears to suffer serious infestation whereas the Pfalz north of the Haardt constantly remains an area of very slight rat infestation.

On the whole, this also conforms with the results of the inquiry, which at certain places are considerably supplemented by the observation.

In summarizing, the following may be said about the density of brown rat infestation in Western Germany. With the exception of the extreme tip of Schleswig-Holstein, the northern coastal sector is definitely an area of positive infestation. This is followed by an area of weaker infestation in the wide belt extending between Lüneburg, Uelzen, Gifhorn, Hanover, Diepholz, Osnabrück, Hamm and Geldern, with the exception of an "island" in the region of Verden, Soltau and Celle. We then have a further number of places above average stretching from the Ruhr district — Essen, Bochum, Dortmund — to Soest and



Explanations to the Figs. 5, 6 and 10

Paderborn to form a compact area infested chiefly by brown rats, possibly incorporating a similar complex ending in the district of Braunschweig. In the adjoining southern sector, the density is once again much lower. This is most obvious between Mayen, Trier, Birkenfeld and Kaiserslautern, an area which apparently already held little attraction for common rats.

East of this area, however, between Kassel, Frankenberg, Hersfeld, Schlüchtern, Giessen, the lower district of the Lahn and Bad Kreuznach, between Worms and Aschaffenburg, Mannheim and Heidelberg, there is a large region of positive brown rat infestation which, with the exception of a small sparsely colonized district around Fulda, Wildflecken and Kissingen, stretches on the one side up the Rhine Valley to Basle and on the other side along the Neckar Valley to Heilbronn taking in a part of the Stuttgart basin. From here the south-eastern boundary appears to run in the direction of Schweinfurt.

In contrast, the remaining regions in the South and South-East are much less populated by brown rats, for example the Swabian Alb, the Black Forest area and Upper Bavaria, in particular. The only exceptions are several areas around Lake Constance, which we know for its association with the common rat, and near Passau, also a sector along the Isar which probably continues into the Donau Valley.

Many features of this distribution remind us of the common rat map but there cannot be any doubt that the general climatic conditions by no means exert the same influence on the geographic distribution of the brown rat. It is intended to carefully check what actually are the influential factors governing brown rat distribution in each individual case. This work will undoubtedly provide us with valuable information for our control measures because we still know very little particularly about the environmental factors which in their effect impose natural limits upon the reproduction of rats*.

Mice

In comparison with the rat density, the infestation of common mice is spread throughout Western Germany (cf. Table 12) in a much more irregular pattern, and is presumably less dependent upon general climatic conditions than upon the different local conditions, for example the large warehouses at the ports and other places dealing with the delivery of goods, or the heavy tourist traffic and the consequent congestion of hotels with their kitchens such as in Garmisch and Berchtesgaden. Nevertheless there appear to be several other large regions of common mouse infestation. This has been confirmed by the results of the inquiry and the observations but we still do not have a satisfactory explanation as to how they came into existence. The distribution of these mouse-infested districts is in certain cases just the reverse of common rat infestation. At the eastern tip of the main southern district of common rat infestation there are hardly any occurrences of common mice but in the adjoining district between Schlüchtern, Wildflecken, Ochsenfurt, Wertheim, Obernberg and Aschaffenburg where there are very few common rats if any at all, the common mouse occurs in unusually large numbers. At other places, however, both types of rodents occur on an equal scale, for example in the positively infested sector between Hagen, Büren and Holzminden. Consequently this more or less eliminates the otherwise obvious explanation that common rats and common mice probably do not occur together because of the competition they offer each other in their fight for existence. It is also just as less likely to be a matter of people simply finding the common mouse to be more disturbing than it really is at places where roof rats no longer exist or have not yet occurred. There is also no case for the assumption that certain observers may have been more sensitive than others in their assessment of the vermin infestation, which if correct would have led to higher values for all classes at their points of observation.

The question, therefore, remains unanswered whether and how an increased occurrence of the common mouse can come about under the influence of the general climatic, countryside, housing estate and economic character of a region. This, however, is a subject which deserves close investigation also from the aspect of the practical prevention of damage.

Of course, allowance must be made for the fact that the general picture of common mouse distribution is always somewhat distorted because of the possibility of common mice being mistaken for common wood mice and field mice which migrate to buildings in Autumn and Winter. Just the same I am inclined to assume, following several series of observations, that the percentage of the latter species hardly ever exceeds 5 to 6%.

* cf. Peters, H.: „Die Wanderratte in der Kanalisation.“ Der Gesundheitsingenieur, No. 13/14, 1951.

R H R+H J

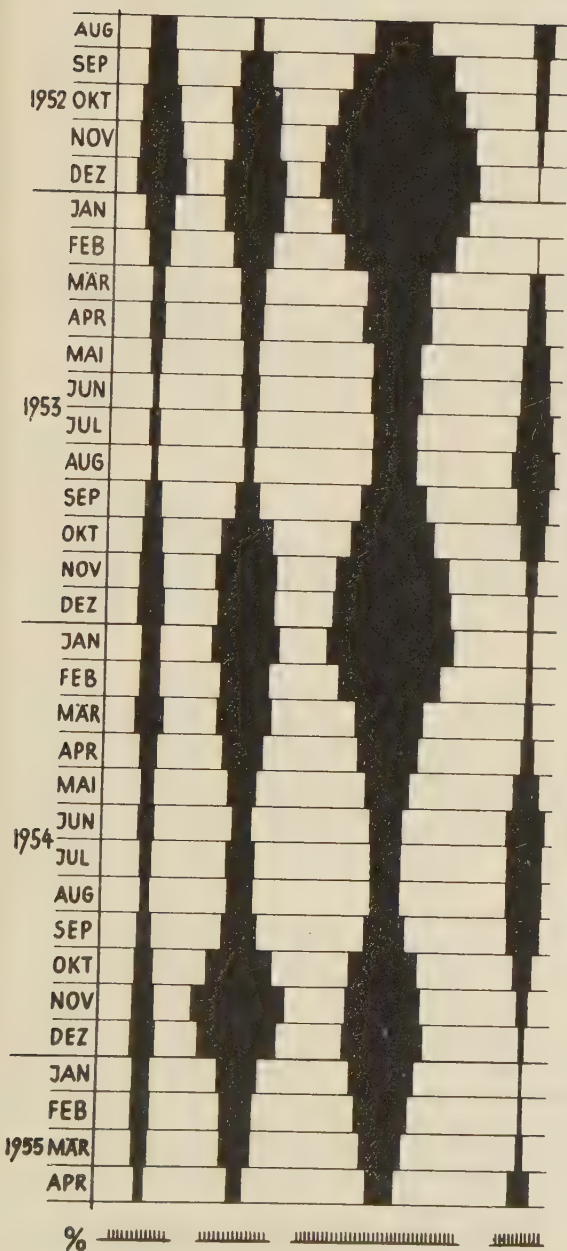


Fig. 7:

Annual curves showing infestation by rodents in buildings and insects outdoors.

Standard: Monthly building index (H, R) and the percentage share of working time (H + R and J).

We have already touched upon the fact that field mice are not completely without importance even when they stray beyond the jurisdiction of the actual preservation of countryside, protection of stocks and plant protection, but we cannot afford to enter into a discussion here on their varying regional density in Western Germany because the danger of bringing in an inadmissible generalization of individual findings would be too great. The distribution of working time incurred for the control of rodents outdoors probably provides the clearest survey of our observations (cf. Table 12). This also shows the slightest deviations between 1953 and 1954. In both years, Hesse and Upper Franconia are at any rate just as constant and as just as high above average as the Pfalz, North Baden, Württemberg and at least a part of Bavaria are below average. On the other hand, however, the control of field mice on cultivated lawns as observed say by a local department responsible for public parks and gardens, covers but a very small section of their living space, and this restriction naturally applies even far more to the observation possibilities of a public health office.

The occurrence of injurious rodents as a whole is subjected, as we know, to very regular seasonal fluctuations.

However, the periods in which the rodent populations reach their peak are by no means identical with those in which rats or mice occur on a particularly large scale. The rat population of a housing estate, for example, is probably greatest in early Summer, provided the progeny of the first main reproduction period become independent in March and April, and are not reduced again by natural selection. Although the rats even in the warm season, do not frequently change their runs which mostly are located in dwelling houses or their immediate vicinity, they do not, however, start to make a nuisance of themselves in the buildings until the cold season sets in, when the storage of Winter stocks again makes the cellars — empty in Summer — a source of attraction for all rodents.

The annual curve of the monthly frequency of infestation — different from that of insects — does not so much reflect the change in the population density of rats and mice as the shift in their nightly search for fodder from outdoors to indoors. As a result they occur more frequently and on a more unpleasant scale, and consequently raise the curve of work involved to a higher level (Fig. 7). However, our attention should actually be concentrated on Spring and possibly late Summer, too — namely the main reproduction periods.

This is also supported by the curve plotted for rats caught per 100 traps set. When it is considered that its peaks are reached in Spring and late Summer, as was the case particularly in 1954 (Fig. 8), then it may be said that this fully conforms with my many years of experience in Stuttgart, namely that at these particular times of the year rats show a greater tendency to be drawn into traps and to be attracted by bait. Presumably these rats are the pregnant females and later the still inexperienced juvenile animals which have just reached their stage of independence.

The corresponding curve for mice is somewhat different, however. Although here, too, a peak may be recognized in March, presumably as an expression of the numerous first Spring litters, the maxima for mice in contrast to rats are not in August but in late Autumn, about October.

The only explanation I can offer for this contrast is that in the cold season, common wood mice and in certain cases field mice, too, on the look-out for

Winter quarters infiltrate into our buildings to join the common mice which are always present there. The common wood mice and field mice are definitely much easier to trap than the common mice — but mostly they are not distinguished from the latter — and cause the trapped rodent curve to rise to a higher level. This, however, is only one possible explanation and, therefore, a closer examination should be made of this interesting difference in the monthly frequency of rat and mouse trappings.

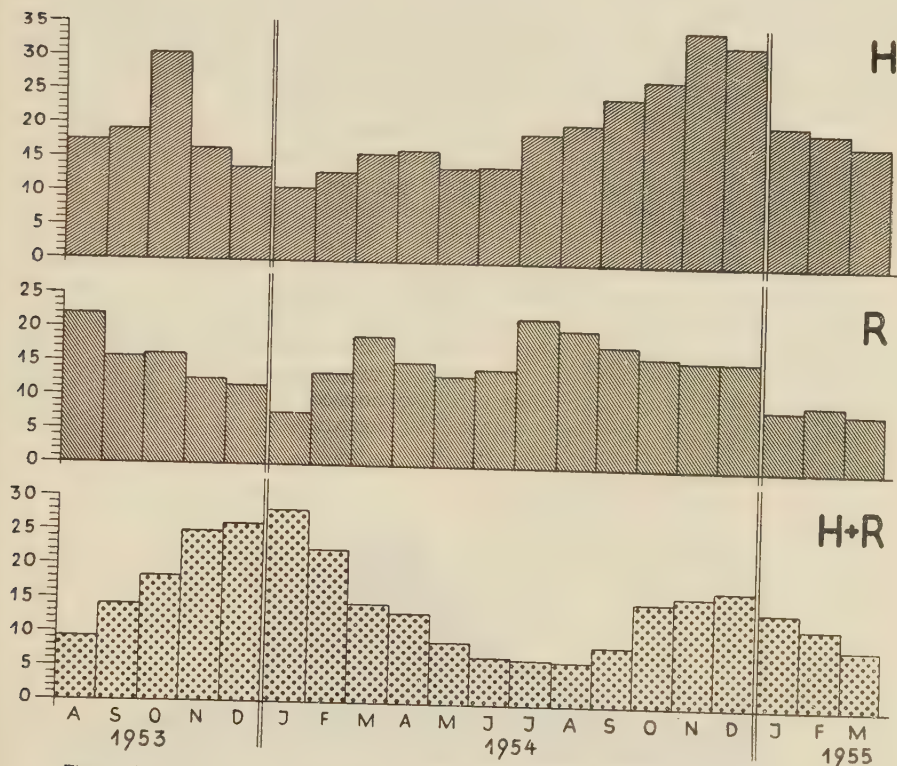


Fig. 8: Annual curves of the infestation of buildings by rodents. Standard: Percentage share of the rodent control in buildings (R + H) as a proportion of the total working time in comparison with the trapped rodents index curves (rodents caught per 100 traps), as an expression of the change in the population density of mice (H) and rats (R).

At all events, these curves provide a new indication of the necessity also to change the methods of rodent control more and more so as to develop a preventative programme which does not aim solely at satisfying momentary requirements but which can be made to conform with natural trends, in other words the life-cycle of the rodents. Consequently the control will be more economical, more systematic and more effective.

In our material, it is only the comparison of the annual means (of the monthly infestation) and the peaks of the Winter curves which furnished us with certain information on the actual infestation density, whereby it is found

that compared with the Winter of 1952/53 the number of infested buildings decreased by about 50 % in the following Winter of 1953/54, whereas there is no such corresponding deviation for mice (cf. Fig. 7 and Table 10).

If it is to be assumed that the decrease in rat infestation is the direct result of successes gained from continuous control measures, then it could be understood from the comparison of the curves that mice are able to fill up more rapidly the gaps in their colonies caused by controls, because they are carried into households and kitchens in particular, warehouses etc. more easily than rats, by hiding in crates of vegetables and also in packaging material.

Should the decrease in rat infestation be due, however, only to external factors over which we have no influence, for example of a climatic nature, then the mice would not be affected by this development.

At all events there can hardly be any doubt about the fact that the rat infestation has become noticeably less in many of our housing estates particularly during the past year.

Insects

What was the situation at the same time with respect to the occurrence of the most important injurious insects in Western Germany?

A clear picture of seasonally caused changes in their population density is furnished by the curve plotted to show the consumption of certain control preparations, for example the aerosol bombs which are so popular at present. As soon as the insects infiltrating into the houses when the warm weather sets in, begin to become troublesome, the consumption of rapidly effective control preparations starts to rise (Fig. 9).

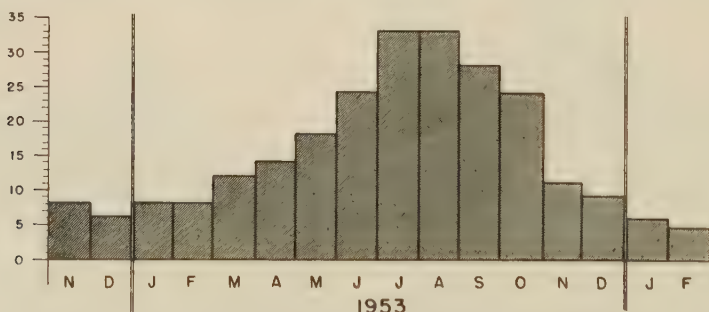


Fig. 9: Annual curve showing the consumption of aerosol bombs.

According to this, the actual insect season in South-West Germany is between May and October provided the weather conditions are extremely favourable, otherwise between June and September — limits which have been fully confirmed by the working time curve (Table 10 and Fig. 7) and also by detailed local investigations. There is, of course, no need to waste any words on the displaceability of the limits in individual cases.

With respect to the question of possible regional differences in the density of insects it will be advisable to take the results of the inquiry as the starting point and to compare firstly the average values of two large regions, "North"

and "South" (Table 9a). The boundaries between these two zones have, however, been drawn more or less at random (cf. Fig. 1).

If we leave out the group of pantry pests which cannot be defined with an adequate degree of certainty (incidentally this omission would not cause any change in the means), we find from this comparison of infestation frequency (Table 9b) that we have an approximate order of the classes in which, with the exception of head and body lice, one would doubtlessly arrange them if it were intended to illustrate their relation to general climatic conditions, i. e. the body insects such as bugs, fleas and crab lice which are influenced practically only by local climatic conditions (in the house), occur everywhere on approximately the same scale whereas the flies and Vespidae which are more or less dependent upon the general weather conditions for their occurrence, appear to be less frequent in the North than in the South.

Table 9: Insect density in the "North" and "South" *.
(Mean according to inquiry.)

a)	"N"	"S"
Gnats	2.60	3.24
Flies	2.98	3.94
Wasps, hornets	1.67	2.86
Ants	2.45	2.84
Moths	2.54	2.45
Crickets	1.17	1.34
Cockroaches	1.97	2.46
Silverfishes	1.85	1.86
Pantry pests	1.06	1.50
Bugs	1.77	1.83
Fleas	1.27	1.07
Lice	1.01	1.26
Crab lice	0.81	0.72
b)	"North" : "South"	
Wasps, hornets	1	: 1.46
Flies		
Gnats	1	: 1.25
Cockroaches		
Ants	1	: 1.15
Crickets		
Silverfishes	1	: 0.98
Moths		
Bugs		
Crab lice	1	: 0.94
Fleas		

* cf. Fig. 1 with respect to the demarcation of both regions.

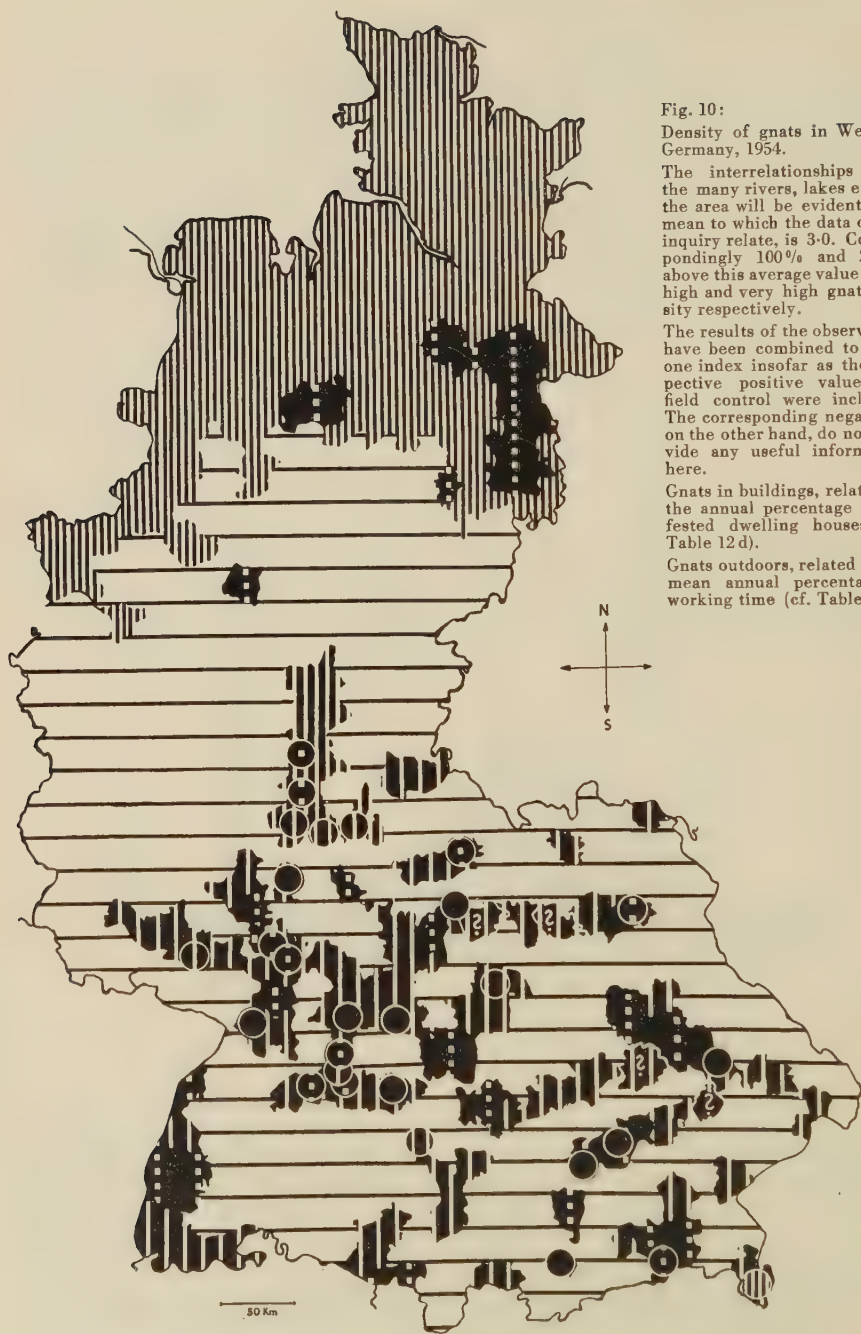


Fig. 10:

Density of gnats in Western Germany, 1954.

The interrelationships with the many rivers, lakes etc. in the area will be evident. The mean to which the data of the inquiry relate, is 3.0. Correspondingly 100% and 233% above this average value mean high and very high gnat density respectively.

The results of the observation have been combined to form one index insofar as the respective positive values for field control were included. The corresponding negatives, on the other hand, do not provide any useful information here.

Gnats in buildings, related to the annual percentage of infested dwelling houses (cf. Table 12d).

Gnats outdoors, related to the mean annual percentage of working time (cf. Table 12g).

In the centre, there are types which either are able to exist just as well outdoors as in buildings, in other words they are also partially subjected to the general weather influences — for example ants and crickets — or for which there are factors other than local and general climatic conditions that are responsible for their distribution. In the case of cockroaches this would be the housing estate and economic character of a region, and for gnats the many rivers, lakes etc.

At all events it may be assumed from this broad comparison that a detailed investigation would bring to light regional differences of far greater clarity. It should not be overlooked, however, that the material at present available does not permit actual proof to be furnished of regional differences in the distribution of certain harmful insects but at the most provides fairly clear indications. Nevertheless these questionable factors continue to remain indispensable records and represent preliminary work so that it can be decided at a later date at which places there are prospects of a detailed investigation furnishing results at all which will justify and make worthwhile the considerable expenditure of a precise analysis.

The basic scientific value and, in particular, the practical significance exact maps showing the density of our most important pests would have, need not be proved in detail.

In order to demarcate large centres of harmful insect density so that an indication can be gained as to the influence of countryside character and climate, we shall have to confine our investigation to a few classes. Body and house vermin will have to be omitted, while with respect to the remaining species (cf. Table 12) it again appears that it is only worthwhile drawing up a cartographic illustration of the results for two groups, gnats on the one hand and ants, Vespidae and flies on the other.

From the inquiry it could not in most cases be established whether the gnats were of the *Aedes* or *Culix* genus (to express it in simple terms), whereas it was possible to a certain extent to make a distinction during the continuous observations, so that it becomes evident here how outdoor and indoor infestations of gnats may occur completely independent of each other, or rather how at certain places the gnat infestation is established chiefly in buildings while at other places the infestation is more or less solely outdoors. Therefore, it is only in cases where both values were negative that there is the likelihood of being confronted — temporarily or permanently — by a region practically free from gnat infestation. For this reason the observations on indoor and outdoor infestation were combined for Fig. 11 (cf. Table 12 d, g and Fig. 11).

As expected the North with its many, and often marshy areas of low country is rather seriously infested by gnats. The southern boundary of this region runs more or less along the highland range where a weakly infested belt commences stretching from the Haardt, Eifel and Hunsrück, through the Taunus and Westerwald north-east to the Harz and in an easterly direction to a point near Hersfeld. Apart from two districts — on the left bank of the Rhine near Mayen and on the Fulda — the negative areas of gnat infestation are interrupted only by a centrally located, but most perceptible sector of serious infestation (*Aedes* in particular), which starts at the northern side of the Oden Forest and stretches to the Francfort, Hanau and Nauheim region, on through the Lahn Valley and into the Frankenberg area.

In the South, prominent areas are the Upper and Central Rhine Valley, and the Neckar from Heidelberg to Heilbronn and on into the Stuttgart basin.

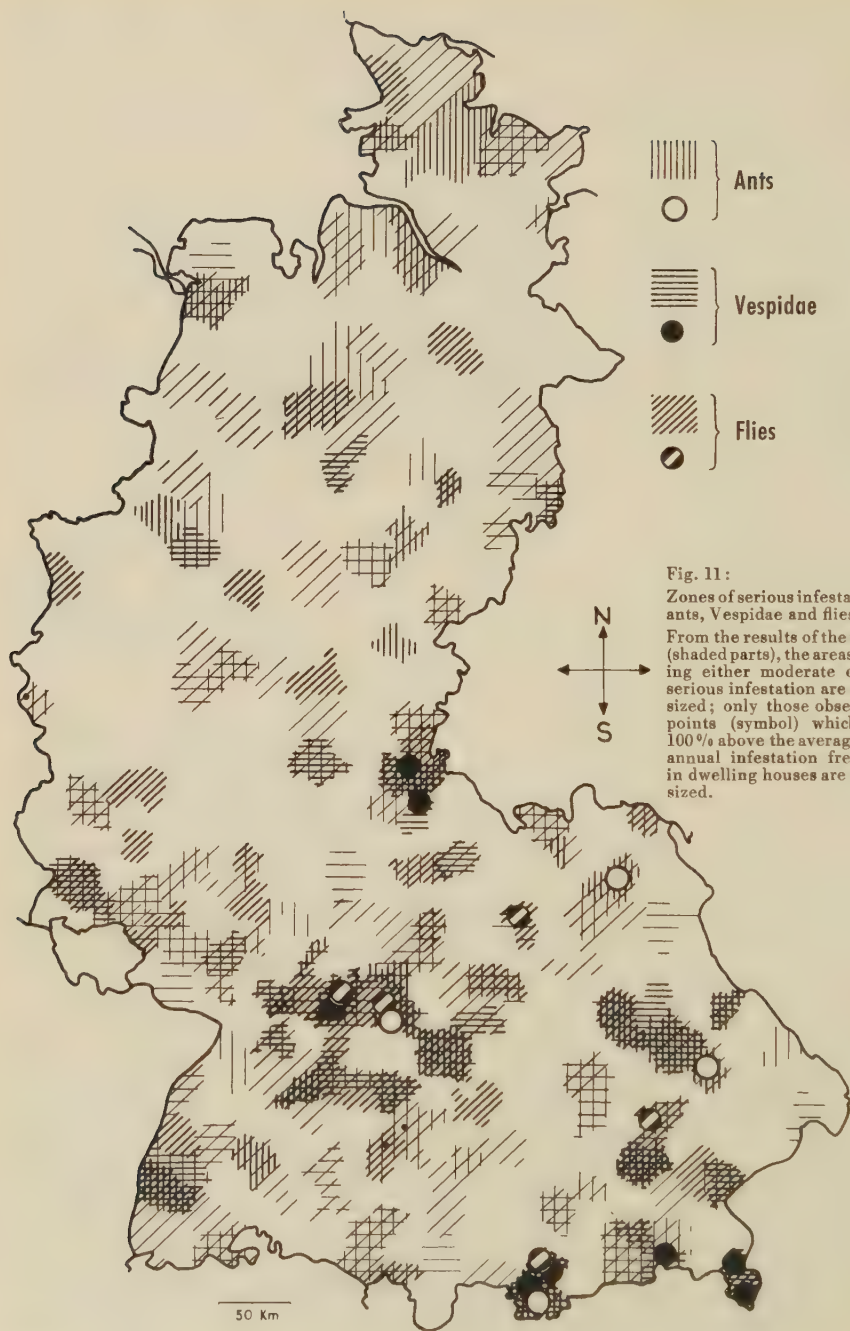


Fig. 11:

Zones of serious infestation by ants, Vespidae and flies, 1954.

From the results of the inquiry (shaded parts), the areas suffering either moderate or very serious infestation are emphasized; only those observation points (symbol) which were 100 % above the average of the annual infestation frequency in dwelling houses are emphasized.

East of this region, there appear to be very favourable conditions for the occurrence of gnats between Kocher, Jagst, Tauber and Main. There is, however, a very clear relation between the occurrences and the countryside character along the Donau Valley from Passau and presumably on to Ulm, also along the Isar. Just as understandable is the high rate of gnat infestation in the Dachau Moos and at places like Lake Constance, between Starnberger and Staffelsee, and in the marshy districts at the upper course of the Inn.

The distribution of the remaining three species — ants, Vespidae and flies — will best be discussed in one group because here far-reaching parallels are to be expected. In actual fact there are several general areas, partly positive and partly negative which appear quite clearly due to overlapping on the common distribution chart (Fig. 11). Firstly, there are the weakly infested highland sectors (with the exception of several "islands"). In contrast there are only four large regions of definite infestation, namely the Upper Rhine Valley, the Freiburg district in particular, then the area between Schweinfurt, Hersfeld, Hanau, Nauheim and Giessen, and finally the centre of North-Baden and Württemberg, stretching on the one side into the Pfalz, and on the other side into Franconia.

Presumably such centres of common density are in the end an expression of favourable climatic conditions, to quote the typical warm zones of Freiburg and Stuttgart as but two examples. In addition to these agreements, certain differences in the distribution of the three groups cannot be overlooked, however.

It should not be forgotten that these are groups including individual species which may be easily subjected to the strong influence of local climatic conditions (in the house).

This would have the least effect on Vespidae, a group with the lowest deviations. Its density admittedly fluctuates between 1953 and 1954 but nevertheless most of the seriously infested observation points remained in the main infestation zones described above, of course with the exception of several small, widely spread areas, and above all the very noticeable region of serious infestation in the southern part of Upper Bavaria, the worst part being near Berchtesgaden.

Similar specific characteristics are also noticeable in the distribution of ants. An explanation for this may be that it was impossible to differentiate from such a summarized collection of material between species like Pharaoh ants which only live in buildings, and those which infiltrate into buildings from outdoors only to seek food. At any rate a surprising feature is the apparently compact zone of infestation in the North, with the Bayreuth area as the most seriously infested district.

With respect to "flies", we understand these with their many more or less synanthropic groups to mean here the chief dominant species, in other words house flies, gad flies, blue bottles and also vinegar flies. Apart from the general contrast between "North" and "South" already portrayed in Table 9, there do not appear to be all those many large fly areas. In addition to the general centre of density, Upper Bavaria is also a positive region of fly infestation which may be due to the fact that it is a marked cattle breeding area. On the whole, however, the districts where fly infestation is above average or even serious, are equally distributed throughout Western Germany.

A mass occurrence of Diptera depends much more upon the economic and housing estate character of a region than does the density distribution of Vespidae and ants.

These comments naturally apply far more to cockroaches. But nevertheless in closing I should like to discuss their distribution at least briefly because after all they still belong to the group of particularly troublesome vermin.

In the housing estates of the entire northern and central part of Western Germany up to a line running from a point near Düren via Siegen and Marburg to Hersfeld, there appear to be very few occurrences of cockroaches, however. Naturally, ports like Bremen, Bremerhaven, Kiel and Lübeck, also large towns like Osnabrück or Aachen, and finally the densely populated Ruhr district between Düsseldorf, Essen, Krefeld and Bochum are an exception. In the East, towns like Braunschweig, Helmstedt, Goslar and Kassel, in particular, are above average and report cases of moderate to serious infestation.

At all these places it is probably the continuous reintroduction of new swarms carried into the area by the large-scale goods traffic on the one hand, and the presence of many restaurants and large factories engaged in the processing of foodstuffs on the other hand, which are responsible for a most perceptible infestation by cockroaches. The same reasons may presumably be put forward in explanation of the existence of a number of cockroach "islands" in the southern sector, for example at industrial centres like Ludwigshafen, Ehingen, Tuttlingen or in large towns like Stuttgart, Ulm and Munich. Moreover, the continued existence of compact regions consisting of old towns also appears to play its part in these occurrences, for example towns like Heidelberg, Ochsenfurt, Dillingen and Rothenburg. In Nauheim and Wiesbaden, the "heating" of the sewer system by warm spring water several years ago offered particularly favourable living conditions for cockroaches with the result that it led to the only mass occurrence of *americana* that I know about.

There can be no doubt that climatic conditions also exert an influence at certain places, for example in the compact positive area in the Upper Rhine Valley between Waldshut and Offenburg, in the Pfalz or in the Stuttgart basin where there is also a most perceptible infestation which might even cause one to consider whether the common name "Schwabens" (cockroach) given to the synanthropic *Blattella* really is invented. But this would amount to unjustified malice because we have just become familiar with this Württemberg area, in particular, as being one highly infested by insects, which without doubt was to be attributed to its favourable climatic location. Moreover, it is not to be expected that there will be any far-reaching conformity with the distribution of ants, Vespidae and flies because cockroaches are far less influenced by general climatic conditions. In this connection, however, it should be mentioned that in Germany the collective term "cockroach" includes two main species which occur practically everywhere, namely *orientalis* and *germanica*, and also two rarer species, *americana* and *australasiae*. These are also joined by the brown-striped cockroach, *Supella*, which first occurred in 1953 and which is in the process of establishing a firm foothold for itself in Germany*.

This finding which, although interesting from the entomological aspect is not particularly pleasing, concludes our survey of the distribution and density of the most important pests of hygiene and public health, and in summarizing

* cf. Peters, H.: „Das Auftreten neuer Blattarien — insbesondere der Braunbandschabe — in Deutschland.“ Z. f. Städtelygiene, 1956/2.

it may be safely said that this attempt, which is the first of its kind to be made in Germany, proved to be most informative. Such large-scale investigations must inevitably remain "rough" analyses but they have one particular advantage, namely they clearly show the general interrelationships and serve as the starting point for further research.

Table 10:

	Rats 100 traps Monthly value	Mice 100 traps Monthly value	Rodent control in buildings (expressed as a percentage of the work- ing time)	Rat infestation density Monthly value*	Mouse infestation density Monthly value*	Insect con- trol outdoors (expressed as a percentage of the work- ing time)
1952						
August	27.5	23.2	12.7	5.3	2.4	4.0
September	22.6	28.7	22.3	6.3	7.3	2.8
October	30.5	21.5	28.2	8.3	11.0	2.8
November	23.7	23.7	33.4	9.1	10.6	1.4
December	22.0	20.2	35.2	10.5	13.5	0.3
1953						
January	22.8	20.1	30.4	6.4	13.0	0.0
February	18.0	18.7	24.5	4.6	8.4	0.3
March	29.1	20.3	13.8	2.8	5.5	3.4
April	24.1	22.6	15.1	3.1	4.9	3.8
May	31.8	24.1	9.9	2.4	3.4	6.1
June	22.3	19.5	11.1	1.5	3.7	6.4
July	19.8	14.3	9.2	2.5	3.2	7.6
August	22.0	17.6	9.4	1.5	2.4	9.1
September	15.8	19.1	14.2	3.6	5.6	6.8
October	16.3	30.5	18.3	4.3	11.2	5.3
November	12.5	16.6	25.0	5.1	13.7	2.6
December	11.6	13.7	26.1	5.5	12.5	1.3
1954						
January	7.8	10.8	28.2	3.9	14.9	1.3
February	13.6	13.0	22.4	4.1	10.8	1.3
March	19.1	16.0	14.6	6.2	11.3	1.8
April	15.4	16.6	13.1	3.7	8.3	2.8
May	13.3	14.0	9.2	2.9	6.0	5.5
June	14.4	14.2	7.0	3.3	4.3	8.0
July	22.2	19.1	6.7	2.3	6.3	7.7
August	20.7	21.8	6.5	1.9	5.9	7.8
September	18.2	24.6	8.7	3.0	7.8	7.3
October	16.7	27.4	15.2	3.8	14.8	4.1
November	16.1	34.7	16.2	4.4	20.6	2.3
December	16.1	32.6	17.1	4.8	17.3	1.2
1955						
January	9.4	21.1	14.2	3.7	8.6	0.6
February	10.0	20.1	11.7	3.8	6.7	0.7
March	9.0	18.3	9.0	3.4	6.6	1.3
April	10.2	23.4	6.1	2.3	3.1	4.5

* No. of buildings : Treatments

Table 11:

Frequency and density of vermin
to pest groups as
Reference value: a) = No. of buildings b) = Effect

Buildings	Reference value	Insects											
Useful type	New infestation index	Gnats		Flies		Wasps Hornets		Ants		Crickets		Cock- roaches	
		1953	1954	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954
Hotels etc.	a)	19-10	17-50	28-74	25-70	3-63	3-40	10-70	10-00	2-29	1-50	5-66	7-9
	b)	10-07	8-62	15-15	12-69	1-91	1-67	5-64	4-92	1-21	0-75	2-98	3-9
	c)	20-00	19-51	30-10	28-73	3-80	3-79	11-20	11-15	2-40	1-70	5-92	8-8
Flats	a)	10-53	5-70	13-19	13-60	1-69	0-90	7-77	6-00	1-08	0-70	4-76	5-0
	b)	23-27	12-26	29-27	29-04	3-76	2-01	17-25	12-77	2-40	1-45	10-58	10-6
	c)	18-75	12-17	23-48	28-83	3-01	1-99	13-84	12-68	1-92	1-44	8-49	10-5
Dining rooms and kitchens (restaurants)	a)	11-38	15-00	52-12	50-00	4-24	6-30	20-40	16-00	3-86	2-60	38-92	29-2
	b)	15-21	18-66	69-68	62-25	5-68	7-88	27-28	19-91	5-17	3-27	52-03	36-3
	c)	8-12	11-45	37-21	38-21	3-03	4-84	14-57	12-22	2-76	2-00	27-78	22-3
Store-rooms (warehouses)	a)	3-66	3-50	6-73	8-00	2-04	1-60	3-45	4-00	0-61	0-50	2-20	2-8
	b)	3-66	3-95	6-73	9-03	2-04	1-81	3-45	4-49	0-61	0-56	2-20	3-1
	c)	15-90	14-04	29-25	32-10	8-89	6-44	15-01	15-94	2-66	2-00	9-56	11-2
Administration buildings	a)	11-10	16-10	21-55	22-90	1-46	0-90	8-53	7-10	1-83	1-00	7-15	9-6
	b)	6-97	10-58	13-56	15-12	0-92	0-58	5-36	4-71	1-15	0-69	4-49	6-3
	c)	19-57	24-26	38-02	34-66	2-58	1-33	15-04	10-80	3-23	1-60	12-62	14-5
Workshops	a)	9-08	9-50	23-36	20-50	3-43	2-40	6-22	6-20	1-55	1-20	5-06	5-1
	b)	7-12	7-62	18-33	16-42	2-69	1-94	4-88	4-95	1-22	0-92	3-97	4-0
	c)	16-84	19-33	43-32	41-62	6-37	4-92	11-55	12-56	2-88	2-33	9-38	10-3
Hospitals	a)	11-61	12-90	38-38	23-90	2-02	2-50	17-67	14-90	7-57	20-00	17-17	12-4
	b)	4-70	4-74	15-55	8-76	0-81	0-91	7-16	5-47	3-06	7-30	6-95	4-5
	c)	10-59	13-33	35-02	24-61	1-84	2-56	16-12	15-38	6-91	20-51	15-66	12-8
Miscellaneous types	a)	4-92	4-30	10-42	11-70	1-49	0-90	4-25	2-70	1-62	0-50	2-74	2-2
	b)	8-08	8-08	17-12	21-65	0-60	1-53	6-98	4-98	3-06	0-90	4-50	4-0
	c)	16-93	17-55	35-86	47-05	5-14	3-34	14-63	10-82	5-60	1-96	9-43	8-8
Sum total	a)	9-30	6-93	15-37	15-42	2-00	1-41	7-27	5-86	1-42	0-88	5-52	5-4
	b)	12-44	9-54	20-57	21-22	2-68	1-95	9-73	8-06	1-90	1-21	7-38	7-4
	c)	17-44	14-61	28-84	32-49	3-76	2-99	13-64	12-34	2-66	1-86	10-35	11-4

estation in buildings according
e of buildings
r space l per 100,000 m² c) = Infestation sum

														Rodents			
Silver-fishes		Pantry pests		Moths		Bugs		Fleas		Head and body lice		Crab lice		Mice		Rats	
53	1954	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954
75	0.40	0.89	2.90	4.45	4.10	4.83	2.60	2.64	1.80	2.43	0.40	9.33	10.40	26.86	23.35	9.39	9.51
39	0.18	0.47	1.42	2.35	2.00	2.55	1.28	1.39	0.87	1.28	0.20	4.91	5.63	14.16	11.51	4.49	4.68
79	0.42	0.93	3.21	4.66	4.53	5.06	2.90	2.76	1.97	2.55	0.46	9.77	12.74	74.07	71.06	25.92	28.93
26	1.10	0.90	0.60	12.51	12.40	0.98	0.60	0.75	0.40	0.34	0.02	0.31	0.10	5.77	5.57	1.73	1.27
30	2.38	2.01	1.21	27.76	26.50	2.19	1.26	1.67	0.88	0.75	0.04	0.70	0.25	12.81	11.90	3.84	2.71
25	2.36	1.61	1.20	22.27	26.30	1.75	1.25	1.34	0.87	0.05	0.04	0.56	0.25	76.89	81.42	23.10	18.57
21	0.90	4.24	9.60	1.97	0.60	0.30	—	0.83	0.40	0.37	—	0.15	0.20	44.00	38.02	11.68	12.21
52	1.15	5.68	11.93	2.63	0.76	0.40	—	1.11	0.48	0.50	—	0.20	0.19	58.82	47.33	15.62	15.20
36	0.70	3.03	7.32	1.40	0.47	0.21	—	0.59	0.29	0.27	—	0.10	0.11	78.06	75.69	20.72	24.30
40	0.30	1.38	1.30	2.35	2.70	0.07	0.10	0.05	0.10	—	—	0.02	0.10	19.32	18.95	12.92	17.50
40	0.38	1.38	1.48	2.35	3.03	0.07	0.89	0.05	0.05	—	—	0.02	0.05	19.34	21.29	12.93	19.65
77	1.37	6.00	5.27	10.23	10.77	0.33	0.31	0.22	0.21	—	—	0.11	0.21	59.92	51.99	40.07	48.00
55	0.70	0.36	0.50	2.11	6.40	1.00	0.10	0.82	0.50	—	—	0.18	0.20	18.07	19.32	5.41	5.29
44	0.46	0.23	0.29	1.32	4.24	0.63	0.05	0.51	0.34	—	—	0.11	0.17	11.36	12.73	3.40	3.48
97	1.06	0.66	0.66	3.73	9.73	1.77	0.13	1.45	0.80	—	—	0.32	0.40	76.95	78.49	23.04	21.50
38	0.20	0.90	0.50	1.68	2.70	0.38	0.20	0.97	0.60	0.25	—	0.38	0.10	21.80	21.61	12.19	12.14
45	0.14	0.71	0.43	1.32	2.13	0.30	0.19	0.76	0.48	0.20	—	0.30	0.09	17.10	17.30	9.57	9.71
98	0.36	1.68	1.10	3.12	5.41	0.72	0.49	1.80	1.23	0.48	—	0.72	0.24	64.12	64.02	35.87	35.97
2	1.00	2.52	1.00	3.53	5.00	0.50	—	3.53	1.00	—	—	3.00	2.50	21.21	29.35	9.09	7.46
1	0.36	1.02	0.36	1.43	1.82	0.20	—	1.43	0.36	—	—	1.22	0.91	8.58	10.77	3.68	2.73
4	1.02	2.30	1.02	3.22	5.12	0.46	—	3.22	1.02	—	—	2.76	2.56	70.00	79.72	30.00	20.27
1	0.30	0.36	0.05	0.95	1.20	0.43	0.20	0.30	0.10	0.09	—	0.82	0.90	10.71	10.75	4.64	4.19
1	0.43	0.60	0.07	1.57	2.14	0.71	0.31	0.49	0.70	0.15	—	1.35	1.63	17.60	19.99	7.63	7.78
2	0.95	1.26	0.15	3.29	4.66	1.49	0.68	1.03	0.37	0.31	—	2.84	3.55	69.74	71.96	30.25	28.03
5	0.75	0.95	1.01	7.17	7.59	1.02	0.55	0.76	0.42	0.40	0.004	1.12	1.12	12.44	11.53	5.10	5.03
7	1.03	1.28	1.39	9.59	10.44	1.37	0.76	1.02	0.59	0.54	0.05	1.49	1.54	16.63	15.86	6.82	6.92
8	1.58	1.79	2.12	13.45	15.99	1.93	1.17	1.43	0.90	0.75	0.08	2.09	2.36	70.92	69.62	29.07	30.37

Table 12:

Frequency

The yearly results of the individual observation point

Basic value:

a-f = Annual infestation figure, based on number of dwelling houses (cf. Table 9a)

g = Percentage of the total working time

Observation point (cf. Fig. 1)	a Ants		b Cockroaches		c Flies		d Gnats		e Moths	
	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954
1	+ 24.5	+ 76.7	+ 800.8	+ 790.0	+ 174.7	- 53.7	+ 305.4	- 77.0	+ 182.0	+ 169.0
2	+ 24.5	+ 91.7	- 71.0	- 32.0	- 72.1	+ 88.2	+ 416.3	+ 764.9	+ 213.1	+ 336.0
3	- 59.5	- 55.0	+ 164.7	+ 40.0	+ 21.6	- 80.2	+ 656.4	- 29.8	+ 200.0	- 53.0
4	- 32.4	+ 6.6	- 92.2	- 72.0	- 86.7	- 89.7	- 97.6	- 84.5	- 49.1	+ 411.0
5	+ 50.2	- 38.3	- 92.4	- 76.0	+ 121.3	- 34.6	- 61.9	- 79.3	- 79.6	+ 44.0
6	+ 51.3	- 50.0	-	-	-	- 78.0	- 44.2	- 47.4	+ 17.5	+ 18.0
7	+ 26.6	+ 1.6	- 20.6	- 84.0	- 94.3	- 66.2	- 64.0	+ 7.0	- 33.4	- 38.0
8	+ 43.0	-	-	-	-	-	+ 163.7	-	- 77.9	- 75.0
9	+ 213.2	+ 538.3	- 45.4	-	- 53.9	+ 194.1	+ 15.6	+ 615.8	- 44.5	- 29.0
10	+ 30.4	+ 23.3	- 85.9	-	- 89.8	- 55.2	-	-	- 51.4	- 89.0
11	+ 80.3	+ 120.0	+ 5.5	+ 10.0	- 6.5	+ 103.7	+ 1.2	+ 80.7	+ 83.9	+ 142.0
12	+ 200.3	+ 271.6	+ 40.0	- 6.0	+ 658.2	+ 340.0	+ 353.6	+ 684.2	+ 86.4	+ 71.0
13	+ 414.8	+ 270.0	+ 40.0	+ 122.0	+ 658.2	+ 634.1	+ 716.7	+ 582.4	+ 273.0	+ 258.0
14	+ 190.1	+ 283.3	- 31.5	- 10.0	+ 135.3	+ 127.9	+ 80.0	+ 236.8	+ 135.1	+ 168.0
15	+ 288.8	+ 525.0	-	-	+ 467.2	+ 597.0	+ 610.5	+ 1361.4	+ 233.5	+ 421.0
16	+ 272.2	- 96.7	+ 21.4	- 58.0	+ 12.7	- 64.0	- 13.7	- 33.4	+ 71.7	+ 63.0
17	+ 26.3	+ 43.3	+ 79.4	+ 100.0	+ 75.1	+ 58.0	+ 71.2	+ 196.5	+ 87.1	+ 93.0
18	- 17.0	+ 28.3	+ 221.8	+ 194.0	+ 435.0	+ 367.6	+ 125.9	+ 157.9	+ 251.3	+ 226.0
19	+ 158.5	+ 240.0	+ 410.3	+ 396.0	+ 55.9	+ 104.4	+ 46.4	+ 189.5	+ 71.8	+ 82.0
20	- 57.4	- 73.3	- 95.4	- 98.0	- 93.4	- 96.3	- 98.2	- 98.2	- 42.0	- 50.0
21	+ 21.2	+ 1.6	- 95.0	- 98.0	- 19.2	+ 277.2	- 60.0	- 28.1	- 76.3	- 59.0
22	- 42.9	- 15.0	-	- 80.0	- 61.6	- 43.4	-	-	- 46.8	- 41.0
23	+ 324.1	-	- 76.3	-	+ 658.2	-	+ 223.7	-	+ 108.9	-
24	+ 363.3	+ 166.6	+ 712.2	- 36.0	+ 557.0	+ 508.1	+ 368.5	+ 1350.9	+ 507.5	+ 566.0
25	- 24.3	- 75.0	- 38.2	- 40.0	- 44.3	- 55.9	- 30.2	+ 86.0	- 53.0	- 26.0
26	+ 136.3	+ 265.0	+ 7.1	+ 88.0	+ 325.5	+ 267.6	-	-	+ 120.2	+ 139.0
27	+ 515.7	-	- 77.5	-	+ 519.6	-	+ 793.4	-	+ 643.5	-
28	+ 92.7	+ 625.0	- 49.4	+ 440.0	- 74.4	+ 98.5	-	- 86.0	+ 58.3	+ 376.0
29	- 10.3	- 61.7	- 51.3	-	- 64.8	- 83.1	-	- 59.7	- 81.5	- 81.0
30	+ 21.4	+ 316.6	+ 177.3	+ 798.0	+ 71.6	+ 515.4	+ 97.0	+ 902.0	+ 20.6	+ 426.0
31	- 55.3	- 60.0	- 58.6	- 12.0	- 94.4	- 97.1	- 94.0	- 98.2	- 58.4	- 53.0
32	- 10.0	+ 55.0	- 19.7	- 60.0	- 4.0	+ 34.5	- 58.7	- 29.8	- 72.6	- 47.0
33	- 53.7	- 16.7	+ 421.0	+ 300.0	+ 36.4	+ 19.1	+ 33.0	+ 170.2	- 36.1	+ 8.0
34	+ 100.6	- 16.7	+ 44.5	- 30.0	+ 341.6	- 74.3	+ 414.0	- 21.1	- 41.4	+ 16.0
35	+ 154.3	+ 195.0	+ 254.2	+ 204.0	- 20.7	- 44.1	- 55.9	- 22.8	+ 137.0	+ 134.0
36	- 68.0	- 78.4	- 85.1	- 68.0	- 73.9	- 91.2	-	-	- 89.6	- 70.0
37	- 81.3	- 75.0	- 13.7	- 18.0	+ 75.3	- 33.8	-	-	+ 52.8	- 71.0
38	+ 26.1	- 26.7	- 49.6	- 40.0	- 85.2	- 78.0	- 90.6	- 91.2	+ 21.4	+ 354.0
39	- 64.4	- 80.0	- 66.8	-	- 48.9	-	- 73.7	- 86.0	+ 20.5	- 77.0
40	+ 121.9	- 125.0	+ 44.7	+ 80.0	+ 109.1	+ 98.5	+ 63.7	+ 278.9	- 17.4	+ 30.0
41	- 37.8	- 55.0	- 52.7	- 86.0	- 85.4	- 84.6	- 91.0	- 94.5	- 79.4	- 65.0
42	+ 114.4	+ 121.6	- 30.0	-	- 49.5	-	+ 90.0	- 42.1	+ 33.2	-
43	- 89.7	- 70.0	- 75.0	- 86.0	- 72.6	- 83.8	- 96.0	-	- 87.2	- 77.0
44	- 90.6	-	-	-	- 55.4	-	-	-	-	-
45	- 49.5	+ 18.3	+ 421.6	+ 100.0	+ 73.4	+ 83.8	+ 36.5	+ 233.3	- 6.0	- 35.0
46	+ 44.3	+ 66.6	- 21.6	+ 40.0	+ 6.2	+ 32.3	+ 15.3	+ 75.4	- 93.3	+ 4.0
47	+ 17.6	+ 140.0	+ 43.9	+ 388.0	- 0.4	+ 14.0	+ 67.5	+ 75.4	- 36.1	+ 16.0
48	- 21.2	- 80.0	+ 242.8	+ 320.0	- 38.2	- 91.2	-	-	- 34.8	- 19.0
49	+ 52.9	+ 158.3	- 41.4	- 84.0	+ 276.4	+ 210.3	+ 66.0	+ 121.0	- 66.5	+ 13.0
50	+ 302.2	+ 233.3	- 47.5	+ 61.0	+ 686.6	+ 427.9	+ 1230.0	+ 993.0	+ 91.9	+ 23.0
51	- 54.7	- 33.4	+ 122.3	+ 300.0	+ 42.7	- 11.8	+ 56.4	- 64.9	+ 59.9	+ 53.0
52	+ 21.6	- 45.0	- 71.6	- 68.0	- 79.5	- 28.0	+ 208.0	+ 329.8	-	+ 58.0

* Control outdoors

min infestation

pressed in percentages above and below the total average

= Average monthly treatment figure expressed in percentages of the total number of buildings

= Average monthly treatment figure expressed in percentages of the total number of buildings

= Percentage of the total working time

f Wasps		g Gnats*		A Rats			B Common mice			C Field mice*	
1953	1954	1954	1953	1954	Index 1954		1953	1954	Index 1954	1953	1954
45.6	+ 88.9	- 39.0	+ 8.0	+ 20.0	+ 53.8	- 57.5	+ 134.0	+ 31.2	- 92.5	- 100.0	
36.1	-	- 100.0	- 89.5	- 86.0	- 88.0	+ 2.7	- 38.5	- 55.3	- 73.6	- 88.4	
66.3	-	- 100.0	- 39.5	- 9.0	+ 35.4	- 57.5	- 39.6	- 40.6	- 46.9	- 74.8	
30.2	+ 55.5	- 67.0	- 89.6	- 94.0	- 92.8	- 56.2	- 70.3	- 77.6	- 77.2	- 88.0	
-	-	+ 34.1	- 55.3	- 94.0	- 84.7	- 97.3	- 91.2	- 88.4	- 78.5	- 48.4	
-	-	- 100.0	- 81.5	- 100.0	- 100.0	- 63.0	- 84.6	- 23.6	- 23.7	- 65.3	
-	-	+ 214.6	- 34.3	- 58.0	- 48.6	- 95.9	- 94.5	- 49.5	+ 75.9	+ 2.0	
557.3	+ 555.5	- 100.0	- 97.4	- 71.0	- 77.4	- 39.7	+ 90.1	- 25.8	+ 18.1	+ 58.7	
49.1	-	+ 25.0	+ 26.8	+ 220.0	+ 213.2	+ 76.7	+ 148.4	+ 66.7	- 26.2	- 10.9	
20.1	-	- 100.0	+ 26.8	- 31.0	- 32.5	+ 76.7	+ 39.5	- 2.5	- 26.2	+ 38.3	
184.6	+ 411.1	- 90.2	- 11.1	- 49.0	- 38.9	+ 46.6	+ 22.0	+ 9.9	- 38.6	- 82.3	
411.8	+ 300.0	- 100.0	+ 66.6	- 26.0	- 15.6	- 53.4	- 48.4	+ 28.1	- 67.3	- 44.8	
491.7	+ 522.2	- 100.0	+ 268.0	+ 209.0	+ 164.6	+ 202.7	+ 158.2	+ 79.7	- 100.0	- 53.3	
-	-	- 100.0	- 66.9	- 60.0	- 62.8	- 20.5	- 81.3	- 79.9	- 99.1	- 26.5	
69.8	+ 366.6	- 100.0	- 92.0	- 20.0	- 50.2	- 20.5	- 79.1	- 78.0	+ 10.9	- 81.3	
-	-	+ 29.3	- 10.5	- 29.0	- 48.3	+ 23.3	- 7.7	- 19.6	- 81.5	- 95.2	
143.2	+ 100.0	- 100.0	- 11.1	+ 51.0	+ 60.3	+ 46.6	- 13.2	- 32.6	- 38.6	- 55.5	
543.8	+ 211.1	- 100.0	+ 210.0	+ 23.0	+ 1.8	- 2.7	- 20.9	- 39.0	- 12.2	- 77.5	
72.8	-	- 100.0	- 11.1	- 57.0	- 49.8	+ 46.6	- 63.7	- 25.6	- 38.6	+ 55.4	
79.9	- 77.8	- 68.3	+ 108.2	+ 74.0	+ 21.5	- 42.5	- 78.0	- 80.5	- 40.6	- 93.1	
17.1	- 77.8	- 100.0	- 72.1	- 39.0	- 51.4	- 76.7	- 68.1	- 57.0	- 77.9	- 93.3	
31.4	-	- 2.4	- 72.1	- 43.0	- 27.9	- 31.5	+ 78.0	- 144.5	- 12.9	- 63.5	
34.3	-	- 100.0	- 94.8	- 66.0	- 76.2	+ 45.2	+ 57.1	- 13.5	- 90.1	- 99.0	
57.4	+ 644.4	- 100.0	+ 256.0	+ 466.0	+ 338.8	+ 117.8	+ 17.6	+ 155.7	- 80.7	- 22.5	
-	-	+ 1147.0	+ 108.2	+ 163.0	+ 307.1	- 42.5	+ 36.3	+ 18.7	- 40.6	+ 113.3	
201.8	+ 1122.2	+ 198.8	- 40.0	- 26.0	+ 105.4	- 58.9	- 56.0	- 61.4	- 95.9	- 71.9	
4.7	-	- 100.0	- 94.8	- 20.0	- 60.0	- 80.8	- 76.9	- 87.9	- 100.0	-	
71.0	+ 1055.5	- 100.0	- 98.5	- 100.1	- 100.0	- 53.4	+ 75.8	- 9.0	- 91.6	- 97.0	
175.1	-	+ 3.7	- 72.1	- 78.0	- 89.0	+ 219.2	- 226.4	+ 89.4	+ 41.8	+ 18.7	
239.6	+ 2677.7	- 100.0	- 94.8	- 100.0	- 100.0	- 89.0	- 86.8	+ 3.6	- 35.4	+ 18.7	
83.4	- 77.8	+ 61.0	+ 58.0	+ 66.0	+ 110.5	- 17.8	+ 8.8	+ 61.1	+ 207.9	+ 75.8	
37.9	- 44.5	+ 639.0	- 34.3	- 9.0	- 51.4	- 79.5	- 48.4	- 31.8	+ 52.6	- 28.4	
231.4	- 35.6	+ 418.3	± 0	+ 6.0	+ 137.9	- 35.6	- 73.6	- 23.3	+ 202.5	+ 108.9	
46.2	-	+ 30.5	- 63.2	+ 3.0	- 22.5	- 31.5	- 71.4	- 73.6	+ 645.1	+ 491.9	
3.0	- 33.4	- 100.0	+ 163.0	- 3.0	+ 31.9	+ 326.0	- 13.2	- 13.2	+ 245.1	+ 281.5	
56.2	- 88.9	- 87.8	+ 58.0	- 83.0	- 59.8	+ 32.9	+ 49.5	+ 113.1	+ 161.0	+ 364.0	
57.4	- 11.2	- 75.6	- 94.8	+ 31.0	+ 7.0	- 39.8	+ 86.8	+ 114.4	+ 42.9	+ 61.7	
71.0	+ 10.0	- 100.0	- 2.5	- 26.0	- 23.6	- 4.1	- 59.3	- 24.9	- 79.4	- 93.1	
6.5	+ 33.3	+ 156.1	+ 108.4	+ 85.0	+ 37.2	+ 46.6	+ 548.4	+ 659.2	+ 60.7	- 38.7	
716.0	+ 2000.0	- 87.8	- 87.0	- 51.0	- 30.5	+ 46.6	+ 34.1	+ 76.7	+ 60.7	+ 41.4	
62.1	- 66.7	+ 656.1	- 13.5	- 66.0	- 57.7	+ 32.9	- 57.1	- 34.0	+ 161.1	+ 84.0	
588.8	+ 626.6	- 100.0	-	- 54.0	- 28.7	-	- 15.4	- 15.0	-	- 34.1	
18.3	+ 21.1	- 100.0	+ 108.2	- 91.0	- 94.7	+ 46.6	- 81.3	- 78.3	+ 60.7	+ 288.8	
-	-	- 100.0	- 13.5	- 51.0	- 66.7	+ 32.9	+ 737.4	+ 280.1	+ 161.1	+ 255.5	
286.4	+ 77.7	+ 46.3	-	+ 9.0	+ 53.0	-	- 78.0	- 63.2	-	+ 522.7	
-	+ 10.0	- 75.6	-	+ 77.0	- 100.0	-	- 31.9	- 32.5	-	+ 569.4	
02.4	+ 263.3	- 94.1	- 2.5	- 17.0	- 18.1	- 75.3	- 58.2	- 73.3	- 100.0	- 100.0	
-	-	- 100.0	- 50.0	- 60.0	- 70.8	+ 39.7	+ 114.3	+ 2.1	- 93.9	- 99.8	
17.7	+ 555.5	- 100.0	+ 251.0	+ 240.0	+ 196.4	- 49.3	2.2	- 7.1	- 88.3	- 56.4	
47.9	-	- 32.9	- 36.8	+ 14.0	- 19.7	+ 152.1	+ 6.6	- 31.7	- 0.5	- 40.1	
-	+ 120.0	- 100.0	- 63.2	- 94.0	- 86.1	- 28.8	- 73.6	- 51.4	- 100.0	- 100.0	
20.1	-	- 63.4	- 42.0	+ 134.0	+ 211.9	- 15.1	- 30.8	- 46.8	- 66.8	- 14.8	

The Control of Damping Off on Tobacco with "Folidol E 605"

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The damping off on tobacco caused by the stem eelworm, *Ditylenchus dipsaci* (Kühn) Filipjev, was observed by Schoevers (3) in 1917 in Holland, and described by him. Kotte (2) encountered this disease in 1942 in the tobacco growing region of Alsace, and availed himself of the opportunity to examine the damage caused by it. The disease had not been observed in Baden up to that time. But in 1953, we discovered what amounted to be almost a 100 % infestation of the stands in a district near Offenburg, and in the Spring of 1954 we conducted our first trial control of the disease. A report of the test has been published in another paper (4).

In reply to the question as to how the eelworm could become so widespread over an entire district within such a short period, there are two reasons which may be given:

1. In this district which specialises in the growing of tobacco on a large scale, tobacco is cultivated again all too frequently in the same fields because of the small acreage available. As a rule it is planted again in rotation every third year, but in many cases also after an interval of only one year.
2. In former years, the sturdier variety, "Geudertheimer", had been chiefly planted, but in 1948/49 growers changed over to the more susceptible variety "Havanna".

Even in 1951, serious injuries caused by damping off were observed in several fields. The injuries are first inflicted by the eelworms forming galls in the cortical layer of the stem after they have penetrated into the plant. While they are gradually making their way up the cortical tissues sometimes to a height of 60 cm, the tissue rots as a result, and this subsequently leads to a stoppage of the sap stream. The rot is then likely to attack the xylem, thus affecting the stability of the plants to such a great extent that they break down when a strong wind is blowing, which means that they have to be written off as a complete harvest loss.

Even though the disease symptoms first occurred in odd places, they were generally widespread by 1953. In instances where not all the plants suffered from more or less uniform infestation, the occurrence of the eelworms was confined to the rows at the edge of the fields. In all probability they migrated in these cases on a broad front from the neighbouring piece of infested land.

The rather unconcerned attitude some farmers adopted towards damping off in the past may be attributed to the fact that the infestation of the fields by stem eelworms did not cause great economic damage every year. In dry years, the damage remains slight from the very outset, and even under favourable weather conditions when there is plenty of rain during the summer season serious disease symptoms do not appear until the tobacco leaf harvest is approaching its end. This, however, was not the case in 1955. In the somewhat lower section of our test field, the drop in the harvest yield of the untreated

plot was 23 % compared with the neighbouring treated plot, this despite the fact that the most serious possible damage had not been caused, in other words the collapse of the foliated stem decayed at its base.

The repeated "watering" of the tobacco plants at the rate of 100 ccs of a 0.1 or, alternatively, a 0.2 % solution of "Folidol E 605" conc. per plant in 1954 had already proved this to be a most practical method for controlling stem eelworms and, therefore, the experiment carried out on a larger scale in 1955 was confined mainly to establishing the most suitable time for starting the treatment. It was decided not to use the stronger concentration in this test because relatively good results had already been obtained with the 0.1 % wash.



Fig. 1: Stem of a tobacco plant seriously infested by the stem eelworm, *Ditylenchus dipsaci*

(Photo: Thill)

The test was based on the following plan. In addition to the untreated plots, it was intended to carry out three treatments in the blocks each consisting of three plots, in the manner depicted below:

0	a	b	c	0
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1st treatment: a, b, c

2nd treatment, one week later: a, b, c

3rd treatment, after a further week: b, c

Therefore, in each block 2 treatments were to be carried out at an interval of one week in plot (a), 3 treatments at weekly intervals in plot (b), and 2 treatments at an interval of two weeks in plot (c).



Fig. 2: 2 adjoining tobacco plants. Left: taken from the edge of the untreated plot
Right: from the edge of the treated plot III c

(Photo: Prof. Dr. Kotte)

It was planned to stagger the start of the treatments so that they would be carried out at the following intervals after the tobacco seedlings had been planted out:

- 1st treatment of block I after 1 week
- 1st treatment of block II after 2 weeks
- 1st treatment of block III after 3 weeks
- 1st treatment of block IV after 4 weeks

A field 14 ares in size which had been planted with tobacco in 1951, was divided into 14 plots each 1 are in area. The seedlings were planted out on May

14, 1955, and on May 21 a start was made to treat the young plants by the soil watering technique in the three plots of block I. The other blocks were treated on May 27 and June 4 as planned. Due to the constant heavy rainfall, however, the fourth treatment could not be carried out on the planned date but had to be postponed until a week later. As a result the fifth treatment was also a week late but this did not affect the result of the test in any way whatsoever, as the data compiled in the following table will show.

Block	Plot	Date of treatments	Tobacco plants infested by eelworms (expressed in %)
I	0		85
	a	21. 5. and 27. 5.	6
	b	21. 5., 27. 5. and 4. 6.	7
	c	21. 5. and 4. 6.	6
	0		72
II	a	27. 5. and 4. 6.	7
	b	27. 5., 4. 6. and 18. 6.	4
	c	27. 5. and 18. 6.	5
	0		90
III	a	4. 6. and 18. 6.	49
	b	4. 6., 18. 6. and 25. 6.	34
	c	4. 6. and 25. 6.	50
	0		100
IV	a	18. 6. and 25. 6.	62

Whereas the rate of eelworm infestation in the four untreated plots is between 72 and 100 %, it amounts to only 4 to 7 % in the early treated blocks I and II, although no particular advantage was gained by repeating the watering treatment three times. If the treatment is not started until three weeks after the seedlings are planted out, the percentage of diseased plants increases most considerably. The eelworms had, therefore, penetrated into the young seedlings very early due to the very rainy weather in May. Consequently they were effectively controlled by the "Folidol E 605" conc. solution applied to the stem base. When the treatment is carried out much later than it should be, some of the eelworms have time to escape to higher parts of the stem, where they are outside the effective range of the preparation, that is with the method of application we employed.

With respect to the evaluation of the test results, it should be pointed out that the success of the control is far greater than the percentages of infestation would suggest. This is best illustrated by Fig. 2 which shows on the right a tobacco stem taken from the edge of plot III c, and on the left the stem of the plant which grew 55 cm away in the untreated plot. The completely decayed

plants in the untreated plot were adjoined by healthy, sturdy plants. Admittedly half of these showed small eelworm galls here and there, but they were hardly of any significance.

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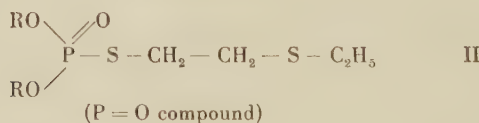
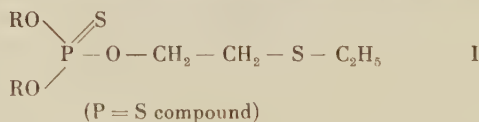
The Chemical Behaviour of Methylisosystox in the Living Plant and the Problem of Residues

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A. Introduction and Published Results

The systemic insecticides, “Systox” and “Metasystox”, when formulated as commercial products contain, in addition to an emulsifier (benzyloxydiphenyl polyglykol ether), the isomeric compounds I and II as their active substance:



In the formulae

R = C₂H₅ for the “Systox” isomeres
and R = CH₃ for the “Metasystox” isomeres

The P = O compounds are referred to in the literature also as Iso-systox or Methylisosystox.

Both active substance groups are largely subjected to transformation and decomposition reactions in the living plant. Exact knowledge of these is essential due to the possibility of toxic residues being left in harvest crops.

The first indications of a transformation of "Systox" active substances in living organisms came in 1952, when Hartley published a short report on the abnormal behaviour of "Systox" in the plant. Details of the investigations on which the report was based, were published in a typewritten manuscript which formed the basis of a paper read at a Plant Protection Conference in December 1952 in Paris. The manuscript written by Heath and co-workers (1953) * is entitled "The Composition of 'Systox' and the behaviour of this insecticide in the living plant".

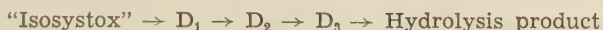
The results may be summarized as follows:

Isosystox, ^{32}P -labelled, is transformed within 24 hours after its application to plants, into compounds largely soluble in water. Two toxic derivatives (D_1 and D_2) which are not Isooktan-soluble but which are readily soluble in chloroform were established with certainty. The mixture of the D_1 and D_2 derivatives can be obtained by shaking out the macerated and aqueous plant material filtered off from the cellulose, by means of chloroform. The chloroform extract is evaporated in vacuum in the presence of water. To separate the two metabolites, the obtained aqueous extract is shaken out with benzene. As a result, one part remains in water (D_1), and the other part passes into the benzene (D_2). A third derivative, D_3 , can be extracted with Butanol from the plant sap already shaken out with chloroform, but only together with a large percentage of natural substances. Its preparation in a pure condition failed. The derivative is said to be toxic to mammals. Table 1 gives the individual derivatives expressed in percentages and the total content of $^{32}\text{phosphorus}$ calculated as "Systox" in ppm = mg/kg:

Table 1: Cabbage plants sprayed with ^{32}P -labelled P = O-"Systox".

No. of days following application	P = O "Systox" %	D_1 %	D_2 %	D_3 + Ions %	Total ppm calculated as "Systox"
6	1	52	37	11	14
14	1	11	53	36	10
20	1	0	38	62	3

It will be seen that the D_1 content of the plants decreases steadily over a long test period. The quantity of D_2 at first increases and then decreases, too, whereas the percentage content of ionic products (+ D_3) constantly increases. Heath et al. conclude from this that Isosystox is transformed in the plant as follows:



* cf. Patent applications of Pest Control Ltd.

1. Austrian application 29. 12. 53 No. A 7851—53

2. French application 31. 12. 53 No. 1 094 671

Priority: Great Britain dated 31. 12. 52

Inventor: D. W. J. Lane and D. F. Heath

Table 2:

	P = O	D ₁	D ₂	D ₃
Molar concentration which produces 50 % inhibition of the human plasma-cholinesterase	3·10 ⁻⁶	2·10 ⁻⁶	4·10 ⁻⁷	1·10 ⁻⁵
Toxicity, intraperitoneal, to the mouse	7 mg/kg	7 mg/kg	10 mg/kg	approx. 10 mg/kg

The next to deal with the problem of transformation products of "Systox" in the living plant were Metcalf and co-workers in 1953 and 1954. Metcalf, too, treated plants with ³²P-labelled P=O and P=S compounds of "Systox". The plants were processed at first by the same method that Heath employed. The chloroform extracts, however, were evaporated to a dry state, taken up in acetone and paperchromatographed by two different methods. Metcalf and co-workers were able to establish only one single transformation product with both methods. This product has a strong cholinergic action. The active substance of "Systox" is transformed to 80—90 % in bean leaves within 24 hours, whereas a 99—100 % transformation takes 4 days in citrus plants.

Other results of the investigations conducted by Metcalf and his study group are published in three papers (T. R. Fukuto et al. [1955], R. L. Metcalf et al. [1955] and R. B. March et al. [1955]).

A most interesting paper has been published by Fukuto et al. (1955) entitled "The chemical behaviour of 'Systox' isomeres in biological systems".

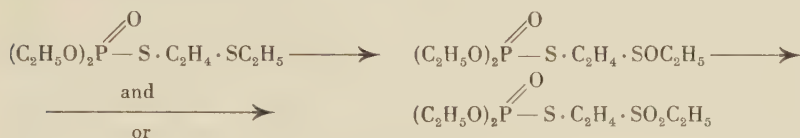
It is a well-known fact that "Schradan" in the plant and in the mammalian organism is subjected to oxidation processes, whereby an aminoxide and a methylol derivative are formed (Kilby, 1953). Similarly, an oxidation of the thioether sulphur of "Systox" isomeres is also feasible. By means of oxidation with hydrogen superoxide and potassium permanganate, it was possible to form the sulphoxides and sulphones of ³²P-labelled P = O and P = S active substances, and also the phosphoric ester which is free of sulphur at the phosphorus atom.

The R_F values, and the values for toxicity, cholinesterase inhibition and stability in aqueous solutions determined in respect of the different compounds have been tabulated.

On the basis of the comparable findings furnished by the paper chromatography, the cholinesterase inhibition values, the systemic effect and finally the toxicity to mammals and insects of metabolites from plants and the synthetically yielded derivatives, the authors have arrived at the following conclusion:

The P = O compound is converted to the sulphoxide in the plant, and can be further oxidized to form sulphone. The authors could not decide, however, whether the sulphone is also formed in the plant in addition to the

sulphoxide. According to the paper-chromatographic methods they employed, sulphoxide and sulphon possess the same R_{F_1} values and, therefore, cannot be identified when together.



In the plant the $\text{P} = \text{S}$ compound is exposed to similar oxidations as the $\text{P} = \text{O}$ compound.

The paper of Metcalf et al. (1955) entitled "The nature and significance of 'Systox' residues in plant materials" summarizes the results of qualitative and quantitative examinations of residues in apples, pears, oranges, walnuts, potatoes and sugar beets. Here too, ^{32}P -labelled compounds were used.

The metabolites of "Systox" isomeres formed in oranges, apples and walnuts are the same as those already found by Metcalf et al. (1954) and Fukuto and co-workers (1955) in the leaves of several other plant species. One to two weeks after the application, there are no traces at all of the "Systox" isomeres originally applied. Here too, the presence of oxidation products is shown by the paper-chromatographic analysis.

It was also established that air and sunlight also oxidize the quantities of "Systox" left on the leaf and fruit surfaces following the spray (Cook, 1954).

At the same time as the transformation of the "Systox" isomeres into oxidation products, there is also a hydrolysis resulting in decomposition products which are no longer toxic. Diethyl phosphoric acid and alcohols are formed. Table 3 gives the times taken for 50 % and 90 % of the applied "Systox" isomeres to decompose in oranges to form compounds that are no longer toxic.

Table 3: Period of the chemical detoxication on orange trees.

Applied compound	Nature of plant material	50 % after x days decomposed	90 % after x days decomposed
$\text{P} = \text{O}$	Leaves	18	38
$\text{P} = \text{O}$	Fruit juice	30	61
$\text{P} = \text{S}$	Leaves	8	16
$\text{P} = \text{S}$	Fruit juice	20	40

In the paper, particular stress is laid on the fact that the sulphoxide of the $\text{P} = \text{O}$ compound is the carrier of the actual insecticidal and systemic efficacy.

Moreover, the experimenters arrive at the conclusion that on the basis of findings made by March et al. (1955) the "Systox" isomeres and their metabolites behave in exactly the same manner in the animal organism as in the plant. This also applies to the subsequent decomposition to non-toxic compounds. Consequently there is no reason to fear that such residues could be left in the organism of warmblooded animals resulting in a cumulative effect which over a period of time might lead to cases of chronic poisoning.

The elimination in the mouse takes place chiefly via the urinal system. 50 to 70 % of the orally administered doses are excreted within 24 hours. 90 % of the eliminated compounds are merely water-soluble decomposition products. The remaining 10 % consists more or less solely of the chloroform-soluble, toxic oxidation products whereas only traces of unchanged "Systox" are left. In the mouse, both the oxidation and the decomposition to non-toxic products take place in the liver.

Summary of the available results:

Heath and co-workers found that $P = O$ "Systox" is rapidly changed into water-soluble metabolites after it is applied to plants. These metabolites can be extracted with chloroform from aqueous plant extracts. By means of a fractionated extraction of the aqueous solutions of "Systox" metabolites with benzene, a separation can be made into two substances, both of which are toxic and possess an insecticidal and cholinergic action.

In contrast to Heath and co-workers, Metcalf's study group was not able to make a separation into two metabolites with the aid of paper chromatography. They found, however, that the transformation of the "Systox" active substance in the living organism is due to an oxidation. Metcalf and co-workers recognized the sulfoxides of "Systox" active substance as an oxidation product. They could not, however, decide whether the sulphones are formed, too.

B. Investigations conducted at the Plant Protection Laboratory, Elberfeld, and the Biological Institute, Leverkusen

I. Formulation of the general problem

Following the publication of papers by Hartley (1952) and by Heath and co-workers (1953), we gave special consideration to the question as to what consequences such a transformation of the "Systox" isomeres in the plant would have for humans and animals with respect to the problem of residues.

In the past, determinations of "Systox" residues on plants were always carried out by the following method only. After the application of ^{32}P -labelled preparations, the plant parts were ashed, and the total radioactive phosphorus was measured and calculated as active substance. Since non-toxic decomposition and hydrolysis products are included in the measurement when this method is employed, the quantities of active substance calculated on the basis of the measured values were most probably too high. In order to obtain the true values for the toxic components, an attempt had to be made to separate these from the non-toxic decomposition products.

We, therefore, tried at first to reproduce the experiments of Heath and co-workers (1953). In fact our tests proved largely successful with respect to both the $P = O$ compound of "Systox" and also the $P = S$ compound which the above-mentioned experimenters had not included in the plant experiments. It was merely with respect to the derivative D_3 that we arrived at different results.

In contrast to Heath and co-workers (1953), we were not able to establish a mammalian toxicity for the derivative D_3 . Even when high peroral dosages were given, digestibility trials with this derivative produced in all cases the same results as tests with correspondingly prepared extracts from untreated plants.

The sulphone compounds of the "Systox" group were produced for the first time in 1951 at the Plant Protection Laboratory of Farbenfabriken Bayer in Elberfeld*. This laboratory also succeeded in obtaining the corresponding sulphoxides** by direct oxidation of the "Systox" active substances. The synthesized "Systox" sulphoxides and sulphones proved to be similar in their properties to the derivatives D_1 and D_2 described by Heath and co-workers.

As the active substances, "Systox" sulphoxide and "Systox" sulphone, can be made in the laboratory in any quantity required and in the purest possible form, it was a simple matter to compare the "Systox" metabolites obtained from plant material with the synthetic substances.

In our work we have dealt chiefly with the further developed commercial preparation "Metasystox" because this far less toxic product has largely replaced the toxic preparation "Systox" in Europe. Since the main effective component in "Metasystox" is Methylisosystox, we conducted our studies solely with this active substance. Henglein and Schrader (1955) proved that the $P = S$ active substances are very rapidly transposed into the $P = O$ isomers in aqueous solutions. According to our observations, this isomerization takes place in the living plant also following application of the $P = S$ compounds. The separation, isolation and identification of the different transformation and decomposition products of Methylisosystox were carried out as separate processes by means of two different methods. In the Biological Institute at Leverkusen, the paper chromatographic method was employed, while at the Plant Protection Laboratory in Elberfeld use was made of the counter-current distribution method.

II. The preparations

The preparations used for the investigations were labelled with ^{32}P . The individual active substances were made by means of the methods developed during the course of many years of research work at the Plant Protection Laboratory, Elberfeld.

		Purity
1. Methylisosystox	$(CH_3O)_2P(O)SC_2H_4SC_2H_5$	98.5 %
2. Methylisosystox sulphoxide	$(CH_3O)_2P(O)SC_2H_4SOC_2H_5$	96 %
3. Methylisosystox sulphone	$(CH_3O)_2P(O)SC_2H_4SO_2C_2H_5$	99 %

* cf. DBP 876 691 of 6. 7. 1951; DBP 876 692 of 7. 7. 1951; DBP 871 448 of 31. 7. 1951.

** Several applications pending.

III. The plant material

The plant material for the qualitative experiments was cultivated in pots in the greenhouse. The plants used in these experiments included *Vicia faba*, potted sugar beets, cucumbers, potatoes and cabbages.

Quantitative studies on the toxic residues were made on both greenhouse and outdoor cultures in the late Autumn, 1955. The different plants are listed in the corresponding experiments.

IV. The application

The application of the preparations generally took the form of spray treatments. The preparation was mixed with "Emulsifier W" in a proportion of 1:1. In the qualitative experiments, the preparation was applied at a concentration of 0.5 % to 0.25 % active substance. In several cases the plants were removed from the pots, dipped by the roots in 0.01 % aqueous solutions of active substance, and then potted again. The period of immersion differed from case to case, and is given in the descriptions of the individual experiments.

V. The countercurrent distribution method

The countercurrent distribution method for separating a substance mixture has several advantages over such other separation methods as adsorption and paper chromatography:

1. Apart from the proportion of distribution of the individual components of the mixture between two non-miscible solvents, there are no other factors which influence the separation effect. The same, exactly reproducible " R_F values" are always obtained for each substance under similar experimental conditions. With chromatography, however, a part is played by the grain size and the moisture content of the absorbent, the rate of flow and the concentration of the solution, while with paper chromatography influence is exerted by the structure of the paper used, the moisture content, the uniform impregnation and many other factors.
2. As the countercurrent distribution is discontinuous, it is possible to measure the quantities of substance in each phase which means that exact quantitative data can be recorded.

VI. Processing of the plants for the countercurrent distribution

In order to carry out successfully the countercurrent distribution of the transformation products obtained in the plants, these products first had to be placed in aqueous solution. The solution had to be freed of all disturbing substances contained by the plants, which impair a clean separation of the liquid phases in the countercurrent distribution. Even at this stage of processing, it was possible to obtain important quantitative information about what happens to the active substance in the plant (hydrolysis).

The letters A to H denoting the individual fractions refer to the corresponding columns in Table 4, in which the activity quantities found in each

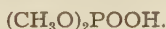
a) General processing plan

Processing	Fraction	Colour	Activity
Plants extracted with methanol →	Residue	A White	10—20 %
↓			
Methanol extract, evaporated in vacuum, diluted with H ₂ O →	Distillate	B Colourless	1 %
↓			
Aqueous solution, smears, extracted with petroleum ether →	Petroleum ether	C Dark green	2—20 %
↓			
Aqueous solution, extracted with chloroform →	Aqueous solution	D Brownish yellow	10—30 %
↓			
Chloroform solution, evaporated, extracted with benzene →	Residue	E Brown	1 %
↓			
Benzene solution, evaporated, extracted with petroleum ether →	Residue	F Brown	1 %
↓			
Petroleum ether solution, shaken out with water →	Petroleum ether	G Bright green	1 %
	Aqueous active substance solution	H Colourless	30—70 %

test are given. The main quantities of activity are in the three fractions A, D and H.

The plant residue A apparently contains inorganic phosphates. This is indicated by the insolubility of these compounds in methanol. They may have been formed as the result of a complete decomposition of the active substance in the plant.

The aqueous solution D might be said to contain dimethyl phosphoric acid:



This is known as the first hydrolysis product of Methylisosystox and its oxidation products, sulfoxide and sulphone. The solubility of the compound in methanol and water on the one hand, and the fact that it is impossible to extract it with chloroform from the aqueous solutions on the other hand, support this assumption.

The aqueous solution H contains the active metabolites of the active substance in the plant.

The quantity of radioactive phosphorus contained in the petroleum ether fraction C is slight several days after the start of the test. However, when the test is continued over a long period it increases considerably, and attains values of up to 20 % of the total ³²phosphorus still contained in the plant 3 to 4 weeks after the application of the active substance (see Table 4). We, therefore, gave special consideration to the chemical nature of this compound which apparently is newly formed in the plant (see Page 132).

b) Experimental method of processing

The upper parts of the plants (stem and leaves) (10 to 20 g) which did not come into contact with the solutions of active substance were cut off, and were disintegrated and extracted in a "Starmix" type mixer using 200 ccs of methanol. The dark green methanol solution was drawn off from the insoluble plant components, and the filter residue was washed pure white with methanol.

The non-extractable activity in the filter residue was measured following decomposition with sulphuric acid perhydrol. Its quantity fluctuated depending upon the species of the plant, the type of active substance and the period the active substance was in the plant, although generally it was approximately 20 to 30 % of the total activity in the plants (activity of residue + activity in the methanol solutions).

The total methanol was distilled off from the methanol extracts in vacuum at 20 to 30 °C. A brownish yellow aqueous solution was left together with dark green water-insoluble smears.

The contents of the flask were diluted with a little water, the smears dissolved with petroleum ether and separated. The petroleum ether solution contained little activity during the first few days following the application.

By means of repeated shakings with 10 ccs of chloroform each time (5 to 6 shakings are mostly adequate), the chloroform-soluble activity was extracted from the obtained brownish-yellow aqueous solution which had been adjusted to a volume of 50 ccs. The chloroform-insoluble activity left in the water may

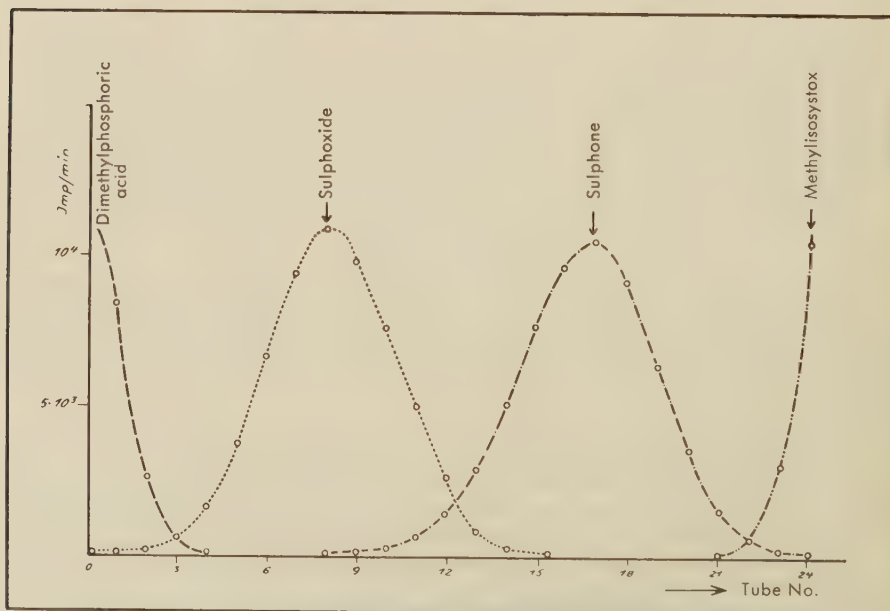


Fig. 1: Distribution curves for Methylisostox, sulphoxide and sulphone between H_2O and $(CHCl_3 + CCl_4 = 1:1)$

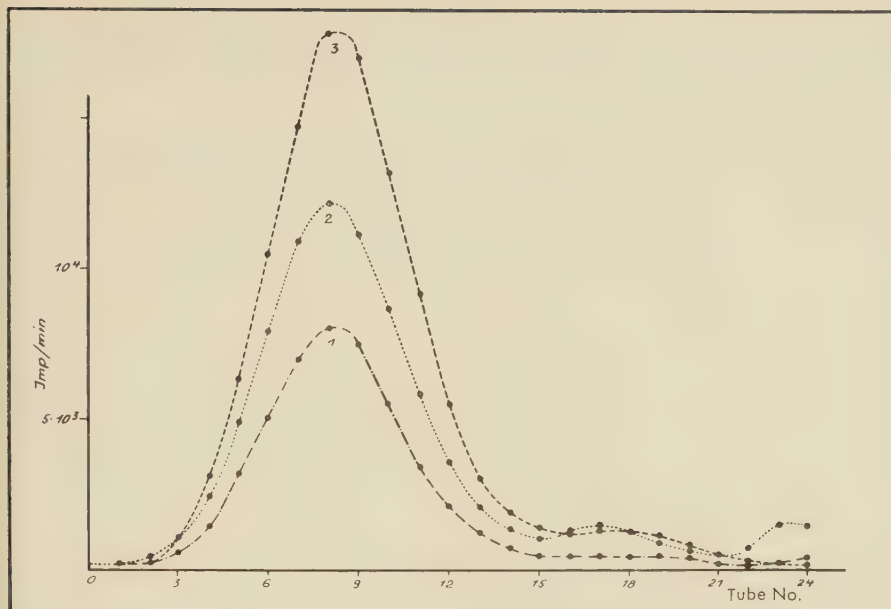


Fig. 2: Plants treated with Methylosystox
 Curve 1: Potatoes, 4 days in solution of active substance
 Curve 2: Cabbage, 7 days in solution of active substance
 Curve 3: Cabbage, 10 days in solution of active substance
 5 days in soil (see Table 4; 1., 2. and 3.).

be said to consist of decomposition products of the active substance, presumably dimethyl phosphoric acid. Its quantity fluctuated between 5 and 30 % of the total activity, depending upon the type of active substance and the length of the experiment.

The chloroform solutions were evaporated to dryness in vacuum. A very small brown residue was left in the flask, which contained the entire chloroform-soluble activity. The residue was extracted several times with hot benzene with the result that it became practically inactive. The bright yellow benzene solution was evaporated and the residue fully extracted with petroleum ether. The total activity at this stage was in the bright green petroleum ether solution. The residue contained hardly any more activity. Occasionally the benzene extraction could also be discontinued, and the chloroform residue extracted direct with petroleum ether. The extraction, however, was performed more easily and more completely when the benzene extraction was interposed.

When the petroleum ether solution was shaken out once or twice with 10 ccs of distilled water, the entire activity passed into the water. The shaken out petroleum ether solution contained no more activity. The completely colourless, clear aqueous solution from which all plant substances interfering with the countercurrent distribution had been removed, was slightly concentrated in vacuum and subsequently subjected to countercurrent distribution.

c) *Determination of the conditions for the countercurrent distribution*

It was established in preliminary tests that the following solvent system is most suitable for the separation of Methylisosystox and its oxidation and hydrolysis products:

Upper phase = Water

Lower phase = Chloroform + carbon tetrachloride (1:1)

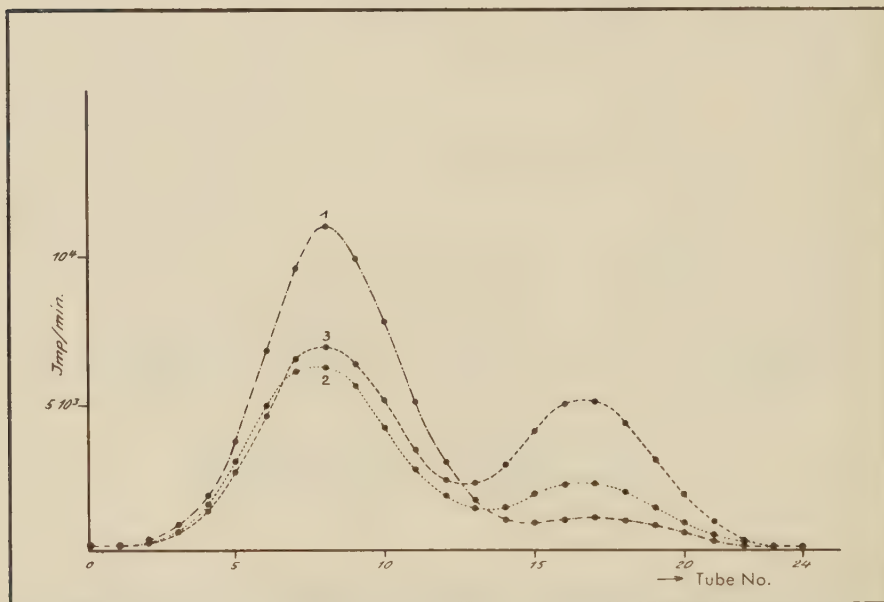


Fig. 3: Plants treated with sulphoxide

Curve 1: Potatoes, 6 days in solution of active substance

Curve 2: Cabbage, 7 days in solution of active substance

Curve 3: Cabbage, 10 days in solution of active substance
5 days in soil (see Table 4; 1., 2 and 3.).

The distribution coefficients (K) of the substances involved have approximately the following values for this system:

Substance	K
Dimethyl phosphoric acid (1st hydrolysis product)	> 25
Sulphoxide	3
Sulphone	0.3
Methylisosystox	< 0.04

The values were determined by dissolving the radioactive substances under examination in chloroform-carbon tetrachloride, and by shaking with the same

quantity of water until the equilibrium of distribution was adjusted. The content in the upper and lower phases was then determined by means of the Geiger-Müller counter.

d) The distribution

The distribution itself was carried out in the 25 phase metal apparatus of Craig (1949). As the lower phase, 175 ccs of chloroform-carbon tetrachloride (1:1) were poured into the apparatus, and evenly distributed over each tube

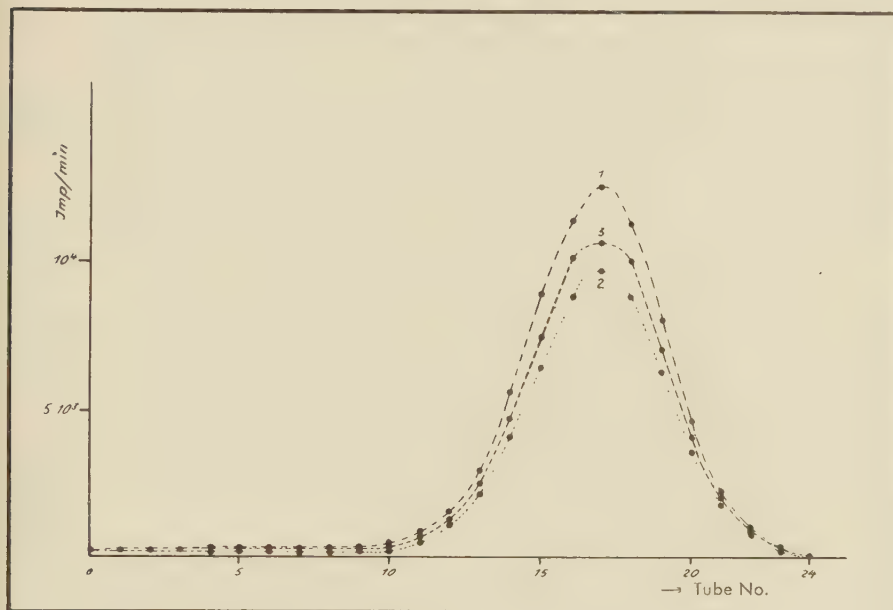


Fig. 4: Plants treated with sulphone
 Curve 1: Potatoes, 6 days in solution of active substance
 Curve 2: Cabbage, 7 days in solution of active substance
 Curve 3: Cabbage, 10 days in solution of active substance
 5 days in soil (see Table 4; 1., 2. and 3.).

by rotating the top section of the apparatus. Then tubes 1 to 24 were each charged with 8 ccs of distilled water, and tube 0 with 8 ccs of the aqueous solution under examination. The countercurrent distribution lasted approximately $1\frac{1}{2}$ hours. On completion of the distribution the contents of each tube were transferred by means of a pipette to a liquid counter, and the activity was measured.

e) Results

In Figs. 1—6, the counts per minute determined in the individual tubes are plotted against the consecutive numbers of the tubes. Fig. 1 illustrates the curves for the pure, synthetically prepared substances, while in Figs. 2—6 the curves are plotted for the metabolites isolated from the test plants.

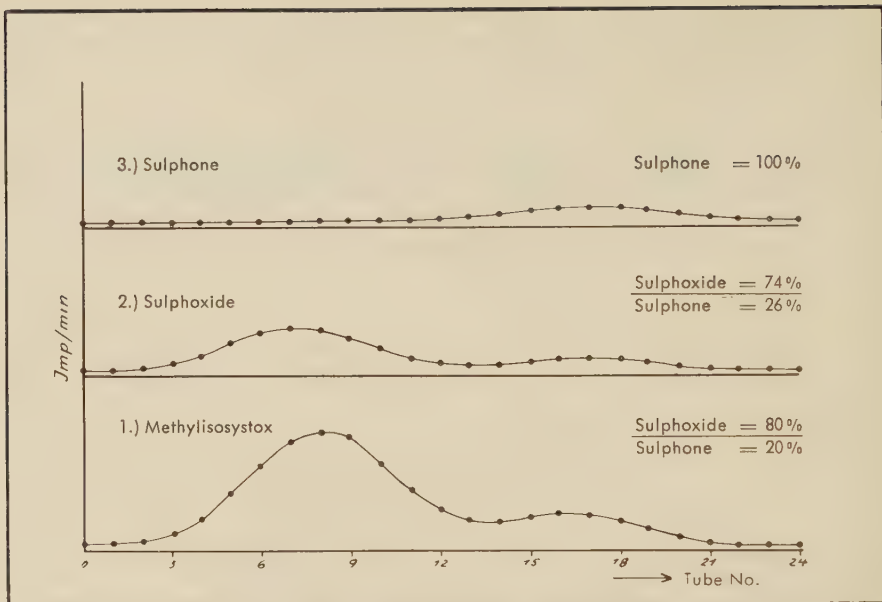


Fig. 5: Cabbage, 10 days in solution of active substance
5 days in soil (see Table 4; 3a).

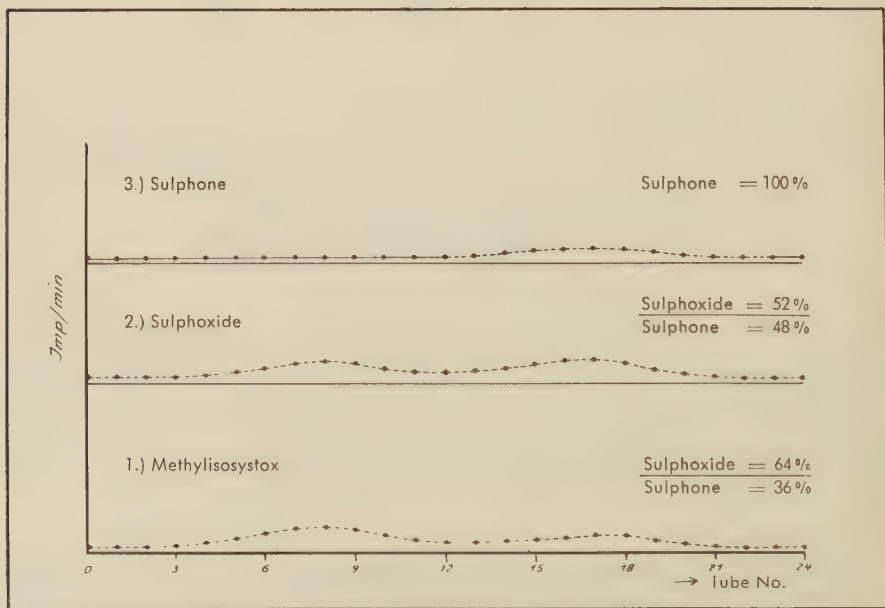


Fig. 6: Cabbage, 10 days in solution of active substance
18 days in soil (see Table 4; 4).

It is clearly perceived on comparing the plotted curves (Figs. 2 to 6) that two substances, the sulphoxide and the sulphone (the latter in a smaller quantity), are obtained from the plants treated with Methylisosystox and sulphoxide. Only the sulphone was recovered from plants treated with sulphone. The formation of sulphoxide from Methylisosystox apparently takes place very rapidly because in all cases the transformation was practically completed as the time of processing. The continued oxidation of sulphoxide to sulphone, on the other hand, is a much slower process.

It is, however, not yet possible to derive from our past experiments any interrelationships with respect to the temporal and quantitative progress of the oxidation and decomposition reactions in the plant.

The only striking feature is that by way of comparison more sulphone was obtained in every case from the plants treated with sulphoxide than from those treated with Methylisosystox. There was no case, however, where the formation of sulphone did not take place at all.

The sulphone itself is not further transformed by the plants but is exposed to the normal hydrolytic decomposition into ineffective substances.

Thus the reaction plan given by Heath and co-workers for the transformation of "Systox" active substance in the plant gains new significance:



is equivalent to



Direct proof of the formation of the two oxidation products, sulphoxide and sulphone, in the plant was finally produced in that the Plant Protection Laboratory at Elberfeld succeeded in isolating preparatively the two substances from treated plants.

VII. Isolating and identification of oxidation products of Methylisosystox from treated plants (cabbage)

a) Preparation of the experiment and processing of the plants

920 g of cabbage (fresh weight) which had been left to stand for 8 days with their roots in 0.01 % solutions of Methylisosystox, were extracted in the "Starmix" with methanol. After the solid plant components had been drawn off, 3 litres of methanol solution were obtained. The methanol was evaporated in vacuum at 30°C bath temperature, and the solution was redistilled to 500 ccs. The solution was filtered, and shaken out five times with 100 ccs of chloroform. On evaporating the combined chloroform solutions dried with Na_2SO_4 , a dark brown, moist residue was left. This was boiled out with 100 ccs of petroleum ether, the bright green petroleum ether solution was poured off, and the undissolved portion was taken up in hot benzene. The resultant greenish-brown benzene solution was evaporated dry, and boiled out again with 100 ccs of petroleum ether. The dissolution with benzene, the evaporation of the solution and the boiling out of the residue with petroleum ether were repeated eight times. The combined petroleum ether solutions (800 ccs) were shaken out twice 20 to 30 ccs of distilled water. The aqueous solution, which now contained the active substance, was concentrated to a volume of 8 ccs in vacuum, and exposed to the countercurrent distribution as described (System: $\text{H}_2\text{O}/\text{Chloroform} + \text{Carbon tetrachloride}$ [1:1]).

At the end of the countercurrent distribution, the sulphoxide and the sulphone were isolated from tubes Nos. 1 to 10 and tubes Nos. 15 to 21 respectively, in the following manner: The contents of the tubes were transferred by means of a pipette to a separating funnel, and the lower phase was separated off. We again shook out the aqueous layer twice with 30 to 40 ccs of chloroform. The chloroform solutions combined with the lower phase were evaporated dry in vacuum, and the Methylisostox-sulphoxide or, alternatively, the sulphone was left behind in the flask.

Yield of sulphoxide (from the tubes Nos. 1 to 10): 49.3 mg

Yield of sulphone (from the tubes Nos. 15 to 21): 2.9 mg

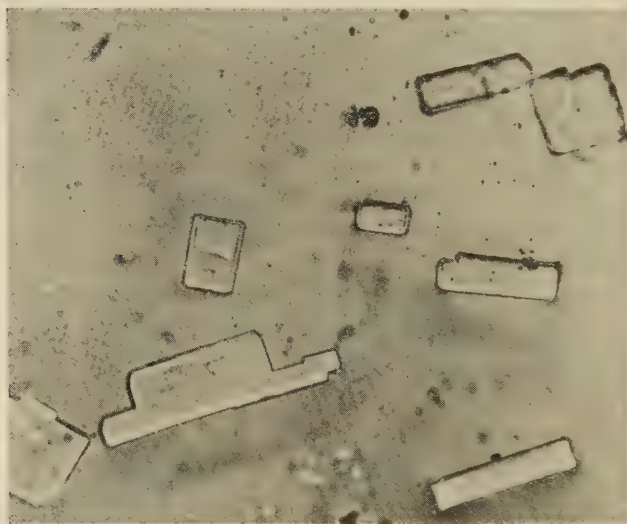


Fig. 7: Methylisostox sulphone, isolated from 1.3 kg of plant material, 9 days following treatment of the plants with 0.01% Magnification $\times 330$. (Photo: Frl. H. Rinn, Pharmacol. Lab. Elberfeld).

b) Characterization of the sulphoxide by oxidation to the sulphone

The main quantity of sulphoxide (approx. 45 mg) was dissolved in 1 to 2 ccs of distilled water, and after adding a spatula-tip of MgSO_4 , it was mixed with 8 ccs of $n/10$ KMnO_4 solution (theory 6.7 ccs). The excess KMnO_4 and the separated MnO_2 were then reduced by passing SO_2 over the solution. The clear solution was shaken out twice with 25 ccs of chloroform, and the solvent was evaporated in vacuum. The residue left in the flask when rubbed with a glass rod solidified completely to form crystals of sulphone with a melting point of 50°C . Yield of 41 mg = 86 % of theoretical value.

c) Characterization of sulphone

In this experiment, due to the small quantity available, the sulphone could not be obtained in crystals. Therefore, the plant test was repeated but this time the plants were placed in 0.01 % solutions of Methylisostox-sulphoxide. In

our earlier tests it had been found that the sulphone was formed from the sulphoxide in the plant more rapidly and in larger yields than when formed from the Methylisosystox.

After the usual processing and countercurrent distribution, the following was obtained from 1300 g of plants treated with sulphoxide:

50 to 60 mg of unchanged sulphoxide (from tubes Nos. 1 to 10)

10.3 mg of sulphone (from tubes Nos. 15 to 21).

The sulphone solidified to form crystals after evaporation of the solvent and rubbing. The crystals were taken up in 0.2 cc of acetic ester, and they were left to crystallize out again on a slide by adding a little cyclohexane, for the purpose of the microphotograph (Fig. 7).

Table 4 gives a quantitative survey of the results obtained in the processing of plants treated with ^{32}P -labelled Methylisosystox, Methylisosystox-sulphoxide and Methylisosystox-sulphone.

Table 4:

Distribution of the different compounds of ^{32}P present in the plant:									
Plant and length of test	Active substance for used treatment	A Inorg. phosph-ate	C I. Petro-leum ether solution	D $(\text{CH}_3\text{O})_2\text{POOH}$	B, E-G Resi-dues	Water extract (H), and components:			Total
		%	%	%	%	Methyl-iso-systox	Sulph-oxide	Sul-phone	
						%	%	%	%
1. Potatoes									
6 days in the solu- tion of active subs- tance (Methyliso- systox 4 days)	Methyl- isosystox	3.9	2.0	7.4	6.7	0	64.5	1.5	66
	Sulphoxide	11.5	1.3	13.0	5.7	0	52.0	7.0	59
	Sulphone	19.0	1.8	28.0	1.9	0	0	39.0	39
2. Cabbage									
7 days in active substancesolution	Methyl- isosystox	18.5	4.5	11.4	4.7	2	52.0	6.0	62
	Sulphoxide	19.0	2.8	12.4	1.3	0	37.0	12.0	49
	Sulphone	21.0	3.5	26.5	1.5	0	0	41.5	41.5
3. Cabbage									
10 days in solu- tion, then 5 days in soil	Methyl- isosystox	27.0	3.5	12.7	0.8	0	46.5	3.5	50.2
	Sulphoxide	27.2	5.6	15.2	1.3	0	27.3	19.0	46.3
	Sulphone	27.8	5.6	32.4	1.2	0	0	26.4	26.4
3a. Cabbage									
10 days in solution of active substan- ce, 5 days in soil	Methyl- isosystox	37.0	9.0	25.3	2.0	—	18.0	4.5	22.5
	Sulphoxide	35.0	9.4	27.4	0.6	—	15.4	5.1	20.5
	Sulphone	31.0	8.5	46.0	0.1	—	0	4.0	4.0
4. Cabbage									
10 days in solution of active substan- ce, 18 days in soil	Methyl- isosystox	57.5	19.0	10.5	1.0	—	2.9	1.6	4.5
	Sulphoxide	54.5	15.2	8.9	1.4	—	2.9	3.1	6.0
	Sulphone	40.2	9.6	25.6	1.0	—	0	1.1	1.1

Experiments 1 to 3 on the one hand, and experiments 3a and 4 on the other hand are from different test series.

VIII. Utilization by the plant of labelled phosphorus originating from the hydrolysis products

A striking feature observed in Table 4 is the large increase of the petroleum ether fraction C following a long test period, in other words at a time when the toxic transformation products of the applied active substance have already decomposed to a large extent. However, as lipide-soluble products are not normally formed from the applied active substances, it appears that the plants utilize the phosphorus of the active substance-decomposition products for building up phosphorus lipides specific to the plant. Proof of the correctness of this assumption was furnished as follows: Cucumber plants were sprayed with a 0.1 % ^{32}P -labelled concentration of Methylisosystox active substance and examined 16 days after the application for labelled phosphorus lipides. The petroleum ether solution C obtained in the usual manner from 190 g of leaves (Page 123) was evaporated dry in vacuum, taken up with hot acetone, and left to stand overnight in the refrigerator at -10°C . Next morning a white precipitate was found to have become separated from the yellowish-green acetone solution. The precipitate was drawn off and washed with cold acetone. It was found to contain 90 % of the activity soluble in petroleum ether.

A similar substance was obtained in the same manner from untreated check plants. Both substances possessed a semisolid, salve-like consistency and were soluble in water with slight opalescence following prior swelling — typical properties of phosphatides.

Table 5: The percentages * of labelled phosphorus, which have been recovered as plant lipides.

	Following treatment with:							
	Methylisosystox after "x" days				Sulphone after "x" days			
	10 %	22 %	35 %	45 %	10 %	22 %	35 %	45 %
A) Greenhouse cultures:								
1. Dwarf beans:								
Beans with pods	26.8	—	18.9	—	20.8	—	15.5	—
2. Tomatoes: Fruits	—	11.8	10.3	—	—	7.4	7.0	—
3. Endives	—	17.1	20.6	—	—	11.5	17.5	—
4. Pea straw	—	—	—	20.5	—	—	—	—
Peas without pods	—	—	—	12.1	—	—	—	—
B) Outdoor cultures:								
1. Apples								
(Jonathan variety)	15.2	—	11.3	—	3.1	—	7.6	—
2. Brussels sprouts	10.75	—	43.4	—	23.7	—	26.5	—
3. Kale	7.8	—	16.8	—	17.8	—	24.7	—
4. Sugar beets:								
a) Leaves	—	20.0	—	24.7	—	29.4	—	15.9
b) Beets	—	4.2	—	1.5	—	12.5	—	5.0
5. Grapes	—	2.5	—	—	—	0.8	—	—

* based on the extractable radioactivity.

The substances were examined in Dr. Scholtan's physicochemical laboratory by paper chromatography. It was revealed that the substances obtained from untreated plants and plants treated with Methylisosystox were identical. Phosphoric acid and choline could be traced in both but there was no indication of a free amino group. They must, therefore, have been lecithins.

An examination of the two phosphatides for cholinesterase inhibition at the Pharmacological Institute (Prof. Wirth) did not reveal any difference between them from the biological aspect either. Consequently, definite proof is furnished that the phosphoric acid formed by the complete decomposition of "Systox" active substances is largely used by the plant for the synthesis of phosphatides.

IX. The paper-chromatographic analysis

The paper chromatography has proved to be most useful for the identification of insecticidally effective phosphoric esters and their transformation and decomposition products. It must, however, be emphasized that due to the solubility properties of these compounds, properties which are often very closely related, exact statements on such substances can only be made when corresponding comparison substances are run through in the same chromatogram. Statements made on the basis of the R_F values formed are not permissible.

The Methylsystox isomeres can be clearly separated from each other and from their hydrolysis product, the dimethyl thiophosphoric or dimethyl phosphoric acid, when the chromatography is carried out with reversed phases. A definite separation of plant metabolites and the dimethyl phosphoric acid is not effected by means of the method with reversed phases. If a normal phase method is used, however, a definite separation of Methylisosystox, its sulphoxide, the sulphone, the dimethyl phosphoric acid and inorganic phosphate is feasible.

The "Systox" and Methylsystox active substances as well as their metabolites and hydrolysis products, can be detected on the paper chromatogram also with a spray reagent in addition to the possibility of being detected with the aid of the radioactive tracer method. A suitable reagent for this purpose is potassium platinum iodide solution. The sulphones, however, do not react to the reagent.

a) Method

Separation procedure

Paper: Schleicher and Schüll 2043 b. Processed 48 to 72 hours by means of ascending development in 84 parts of n-butanol and 14 parts of aqua dest. (Fig. 8).

Developing reagent: potassium platinum iodide solution 0.5 g K_2PtI_6 , 2 ml of hydriodic acid for stabilization and H_2O ad 1000 ml.

The spray reagent keeps for an unlimited period. After the papers have been dried in air, they are sprayed with the reagent. After a short time, white or yellow spots appear on a pink-coloured background. In light,

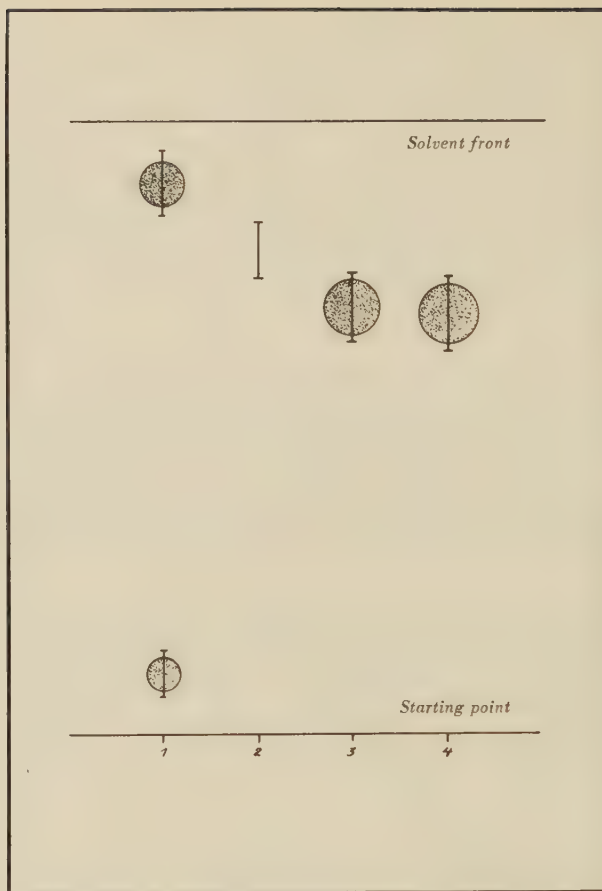


Fig. 8: Paper chromatogram of the transformation product in *Vicia faba* plants following a spray treatment with ^{32}P -labelled Methylisosystox

1. (bottom) Dimethyl thiophosphoric acid
1. (top) Methylisosystox
2. Methylisosystox-sulphone
3. Methylisosystox-sulphoxide
4. Transformation product isolated from the plant

The circles represent the formation of spots with potassium platinum iodide solution, whereas the radioactive zones are marked by the lines.

the background fades within a few hours. All "Systox" and "Metasystox" derivatives, with the exception of sulphone, can be detected immediately. An additional evaluation for the application of ^{32}P -labelled preparations, was made by measuring the chromatogram with the Geiger-Müller counter and by preparing autoradiographs.

b) The processing of the plant material

The processing of the plant material for the qualitative analysis is done in the same manner as described for the countercurrent distribution (cf. Page 123), but only up to the chloroform extract.

The chloroform extract is evaporated in vacuum to approximately 1 ml in a micro distilling apparatus. The distillate is free of radioactivity.

The aqueous residue originating from the shaking out of the chloroform, is evaporated in vacuum to 2 ml in the same manner as the chloroform extract. Here too, the distillate is free from radioactivity.

Both distillate residues are immediately placed in the refrigerator at a temperature of 0 °C, and kept ready for the paper-chromatographic analysis.

X. Results obtained by the paper-chromatographic method for the application of labelled Methylisosystox by spraying

Only one transformation product was found by means of the above separation procedure in chloroform extracts of *Vicia faba*, which were obtained 6, 13 und 21 days following the application. It was indentified as Methylisosystox-sulphoxide because in these experiments the sulphone was used as the labelled comparison substance.

On the other hand, we found both the sulphoxide and the sulphone in cucumbers plants following an application of Methylisosystox in Autumn 1955 (Fig. 9).

9 days following the spray of 0.02 % active substance at the standard rate of application, the paper-chromatographic analysis showed the proportion of the toxic percentage of sulphoxide to sulphone to be 71.5 to 28.5 %.

In one experiment with a fivefold overdosage of the preparation, the quantity of sulphone formed was considerably smaller. After 6 days the proportion of sulphoxide to sulphone was 93.2 to 6.8 %.

The aqueous plant extract only contains dimethyl phosphoric acid and orthophosphate after being shaken out with chloroform. Neither substance is toxic to warm-blooded animals.

XI. Investigations on the organism of warm-blooded animals

Once we had established that sulphoxide and sulphone are formed in the plant as the primary and secondary transformation products respectively of Methylisosystox, it appeared advisable to determine how these compounds behave in the organism of warm-blooded animals and what consequence the constant consumption of harvest crops will have when traces of sulphoxide are continually taken.

The LD₅₀ of Methylisosystox and its oxidation products is approximately 20 mg/kg for white mice. A number of white mice each weighing 20 grammes were each given 200 gamma of ³²P-labelled sulphoxide administered perorally or subcutaneously in aqueous solution. This corresponds to a dose of 10 mg/kg, in other words half the LD₅₀ value. The animals very soon displayed the typical symptoms of poisoning, but they all survived. The animals were killed after varying intervals of time, and then liquid ashed in a mixture of sulphuric and nitric acid. The radioactivity in the whole body was determined and calculated as Methylisosystox-sulphoxide.

Table 6: Percentage of ^{32}P left in animal's body after application of 10 mg/kg of Methylisosystox-sulphoxide to white mice.

Time following application	Quantity found in body and calculated as sulphoxide with	
	a) subcutaneous dosage = % of applied quantity	b) peroral dosage = % of applied quantity
15 hours	2.81	2.25
5 days	1.49	1.49
10 days	0.83	1.52

It will be seen from the above figures that the percentage of ^{32}P , calculated as sulphoxide present in the animal's body after 15 days is only 2.25 to 2.81 %, despite the high dosage. In other words, 97 to 98 % of the preparation are eliminated by mammals during this short period.

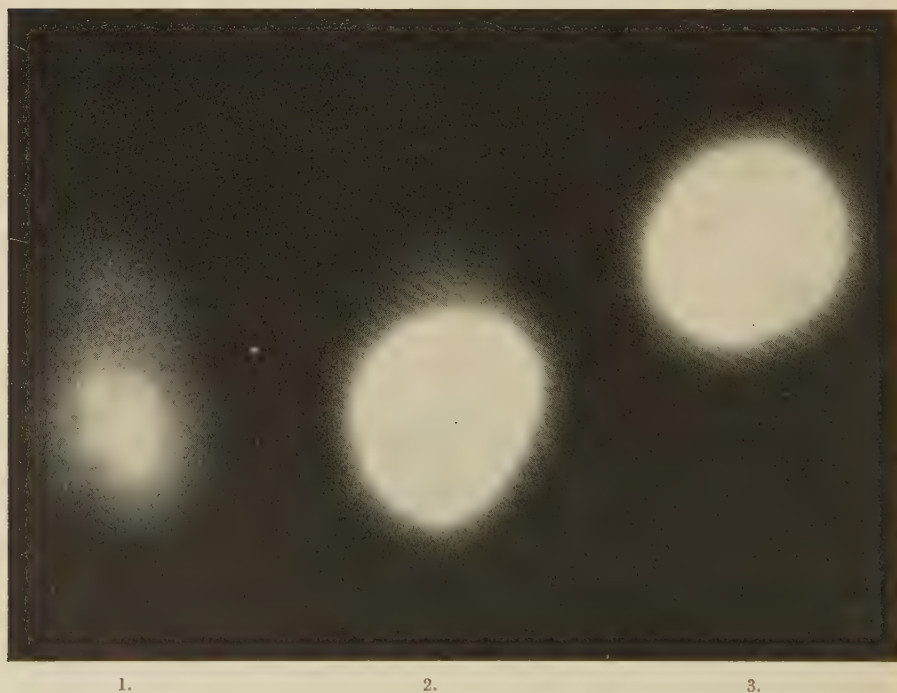


Fig. 9: Section taken from an autoradiography of paper chromatogram of cucumber plants sprayed with ^{32}P -labelled Methylisosystox.

1. Normal spray
2. Fivefold overdosage
3. Labelled sulphone used as the check

Table 7:

Investigations of Methylisoxystox-sulphone residues for 1955
Date of application: Sept. 26 to 30, 1955

State of application Sept. 20 to 30, 1953

	Toxic residues following											
	a) Methylosystox sprays						b) Methylosystox-sulphone sprays					
	No. of days following application						No. of days following application					
	0	10	22	35	45	51	0	10	22	35	45	51
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
I. Greenhouse cultures												
1. Dwarf beans												
a) Leaves	63.90	—	—	—	—	—	—	—	—	—	—	—
b) Beans with pods	—	0.145	—	0.109	—	—	—	0.424	—	0.189	—	—
2. Tomatoes												
a) Leaves	22.90	—	—	—	—	—	—	—	—	—	—	—
b) Fruits	—	—	0.241	0.253	—	—	—	—	0.550	0.296	—	—
3. Endives	38.62	—	9.77	1.01	—	—	46.73	—	2.160	0.360	—	—
4. Peas												
a) Leaves or Straw	35.40	—	—	—	0.000	—	—	—	—	—	—	—
b) Peas without pods	—	—	—	—	0.000	—	—	—	—	—	—	—
II. Outdoor cultures												
1. Apples (<i>Jonathan</i> variety)												
a) Leaves	—	0.556	—	0.434	—	—	—	0.305	—	0.176	—	—
2. Brussels sprouts	—	0.702	—	0.0181	—	—	—	0.561	—	0.0201	—	—
3. Kale	—	0.965	—	0.0531	—	—	—	0.294	—	0.0232	—	—
4. Savoy cabbage	24.14	—	—	—	—	—	24.53	—	—	—	—	—
5. Sugar beets												
a) Leaves	19.35	—	0.301	—	0.724	—	—	—	0.067	—	0.248	—
b) Beets	—	—	0.273	—	0.507	—	—	—	0.0136	—	0.411	—
6. Vines												
a) Leaves	35.60	—	—	—	—	—	95.00	—	—	—	—	—
b) Berries	1.15	—	0.812	—	—	1.305	1.72	—	1.530	—	—	1.24

XII. The determination of toxic residues in harvest crops following sprays of Methylisosystox and Methylisosystox-sulphone applied at standard rates to different cultures

The extraction procedure used for Craig's analysis (see Page 123) had revealed that the total toxic percentage which is present in the plant following the application of both Methylisosystox and the corresponding sulphone, passes into the chloroform phase. We, therefore, made use of this possibility and determined in the following manner for labelled compounds the toxic residues present in harvest crops in the form of sulfoxide and sulphone. (See L. H. Stein, 1954.)

20 to 100 g of plant material are minced in the "Starmix" with 5 to 6 times the quantity of methanol, drawn off, and the cellulose residue washed with methanol until it is completely white. The methanol distillate is evaporated in vacuum at room temperature until all the methanol is distilled off. If necessary, it is filled up with water to 30 ml, and shaken out four times with equivalent quantities of petroleum ether. Subsequently it is extracted four times with equal volumes of chloroform. The entire toxic portion is present in the chloroform. The quantity of the toxic portion is determined by measuring the radioactivity.

Table 7 gives the determined residues in mg of toxic substance per kg plant material = ppm at different times following the application. The application was carried out from September 26 to 30, 1955.

On page 129 it was mentioned, that from the plant tests which have been carried out up to now no clues can be derived as to the chronological sequence of the detoxication (hydrolysis) of the active ingredients. However, there is reason for assuming that the hydrolyzate above all depends on the outdoor temperatures and on the pH of the sap. Besides, there will probably be other factors too, as conditions of light, stage of growth of the plants etc. which play a role.

C. Summary of author's results

The chemical behaviour of Methylisosystox, Methylisosystox-sulfoxide and Methylisosystox-sulphone was examined in the plant and in the mammalian organism by means of ^{32}P -labelled compounds. The following results were established:

1. In conformity with the observations of Heath, two toxic transformation products of Methylisosystox are formed in the plant. In addition to sulfoxide, we also detected and identified for the first time the Methylisosystox-sulphone in plants treated with Methylisosystox. Both compounds were recovered preparatively in pure form from treated plants, and identified (the sulfoxide by oxidation to sulphone in 86 % yield, the sulphone by determining the melting point and crystal form). The sulfoxides and sulphones of "Systox" active substances are identical with Heath's derivatives D_1 and D_2 . Proof of this is furnished by the partition coefficients between benzene and water which we found in respect of the synthetic compounds, and those given by Heath for the "Systox" metabolites.

2. Both Methylisosystox itself and its oxidation products, sulphoxide and sulphone, are exposed in the living plant to the normal hydrolytic decomposition to non-toxic compounds. The first decomposition product is dimethyl phosphoric acid, and the end product is orthophosphoric acid.

From our experiments carried out to date, it is not possible to say that there is any definite conformity to law concerning the speed of the oxidation and decomposition reactions of "Systox" active substances in the plant. It is, however, likely that the weather conditions, above all the temperature and light conditions, play a decisive part in this.

3. Proof was furnished that the phosphoric acid formed by complete decomposition of the "Systox" active substances is largely used by the plant for the synthesis of phosphatides (in particular lecithin).
4. We extended our qualitative analytical method for ^{32}P -labelled substances quantitatively, and obtained true residual values which are considerably lower than those so far calculated at random on the basis of the total content of ^{32}P .
5. The Methylisosystox-sulphoxide primarily formed in the plant is excreted quantitatively from the organism of warm-blooded animals within a short time. Considering that 97 % of the applied quantity is excreted within 15 hours from the mouse even when a high dosage of sulphoxide is administered, cases of chronic poisoning cannot be caused following the consumption of such small quantities as represented by the residues in the harvest crops.

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